Promotion of Underutilized Taro for Sustainable Biodiversity and Nutritional Security in SAARC Countries

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Foreword

Food habit of South Asian people is cereal based and mostly depends on Rice and Wheat for their staple food. Although, there are thousands of indigenous plant species which are rich in nutrition and locally or regionally adapted and accepted but not included in the modern food systems. These crops are labelled as underutilized, minor, or neglected crop such as, taro in South Asia. Taro has been used as food for over 9,000 years, making it one of the world's oldest food crops. Taros are rich in starch, minerals and vitamins. South Asia is thought to be one of the origins of taro and it can be found to grow both in wild and cultivated forms in this region. Aroids or taro, a category of non-commodity cultivated and wild species, which are share of a large agricultural biodiversity has prerequisite for crop improvement program.

Currently, global food security is largely dependent on a handful number of crops. Modern agricultural systems promote the cultivation of high-yielding crop species, with the intensification of a limited number of species. This has caused a decline the cultivation of traditional crops; yet such crops have potential to improve food and nutritional security for the current increasing population of the world. To address the demand of increased production and greater diversification of crops, taro can play a major role in this context. In South Asia context aroids or taro also can play a vital role to reduce the risk of over-reliance on very limited numbers of major crops, way to increase sustainability of agriculture through fossil fuel-derived nitrogen fertilizers and fuel for agriculture fossil, also preserve and celebrate cultural and dietary diversity. To share knowledge on possible way to develop mechanisms for regional cooperation for developing program on Taro (such as pest and diseases, germplasm collection and breeding for better keeping quality etc.), this book can play a significant informative role for SAARC Countries.

This book is the compilation of the country status papers presented by professionals of eight Member States (Afghanistan, Bangladesh, Bhutan, India, Nepal, Maldives, Pakistan and Sri Lanka) and two invited speakers during the consultation meeting organized by SAARC Agriculture Centre on 03-04 November 2020 in virtual mode. The regional initiative has also generated a variety of recommendations, which can be implemented by Member States. This book is on the status of taro in South Asia, dealing with the importance of neglected crops to commercial and livelihood approach sustainable agricultural production. It seeks to bridge the scientific knowledge gap, and it presents updated information on plant nutrition of different countries. Summary and synthesis are also incorporated to provide a comprehensive picture for conservation, collection and R&D progress and prospects in the field aroids or taro in SAARC region in achieving the goal of food security.

I would like to acknowledge the contribution made by the focal point experts of SAARC Member Countries in preparing a comprehensive paper and participating in the consultation meeting. The contribution of Dr. Nasreen Sultana, Senior Program Specialist (Horticulture) to the conceptualization, initiation, technical guidance, inputs, reviewing and editing of this publication is duly acknowledged. Special thanks are due to Dr. Sreekanth Attaluri, Senior Program Specialist (Crops) and Ms. Fatema Nasrin Jahan, Senior Program Officer (NRM) for their contributions are duly acknowledged. I personally hope that this publication will provide detail and comprehensive information on available resources and present status on taro and also future activities related to nutritional security in South Asian Region. I would welcome receiving feedbacks, comments and suggestions from readers for our future endeavors.

Dr. Md. Baktear Hossain
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Chapter 1

Status and Scope of Promoting Underutilized Taro for Sustainable biodiversity and nutrition security in SAARC Countries

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Abstract

Taro is mostly an under underutilized crop in South Asian countries though it has been cultivated as vegetable in India and Bangladesh for a long time. It is also used as vegetable in Nepal, Pakistan, and Sri Lanka on a limited scale. But it is rarely used as vegetable in Bhutan and Afghanistan though it is found to grow in the natural vegetation in every country of this region. Among the SAARC countries, India has made huge progress in the research and development of taro. Considerable research attempt has been made by Bangladesh, Sri Lanka, Nepal, and Pakistan. Although, once taro was the part of staple food in the Maldives but due to crop loss by diseases, gradually it has lost its place as a staple food. Lack of awareness of the nutritional and commercial value of taro is the prime reason for its underutilized status in South Asia. In Compared to staple cereals, starch, fiber, vitamins, and minerals content in taro is higher which needs to be utilized for addressing nutritional security in South Asian countries by promoting taro as an alternative source of food. Globally, in developing countries, taro trade is expanding due to its commercial and industrial values. In this context, South Asia has tremendous potential to enter the global taro market.

Introduction

South Asian countries with potential depletion of natural resources face huge challenges in providing sufficient food to feed the growing population in their countries. It is the most populated region in the world with about 1.749 billion people. The problem will grow more acute in the next 30 years as the global population increases to 8.5 billion by 2050. Food security especially nutritional foods will become a dominant issue. it is important to explore new opportunities in terms of resources, particularly underutilized crop species. In this context, research must be given the focus on underutilized crops and alternative food sources. In 2020 the Global Initiatives, the African Orphan Crops Consortium's, (AOCC) has listed taro among the 101 traditional orphan or neglected crops. Similar statements can also be found on the Crop Trust webpage (Crop Trust, 2020) which has tremendous potential to contribute to global food security (Li, and Siddique, 2018) but has been hitherto under-exploited.

Taro is a member of edible aroids under the Araeace family. Although each member of edible aroids has their distinct biological name such as *Colocasia esculenta* is the name of true taro but in many English scientific languages *'Taro'* is commonly applied to all edible aroids as a group (Plucknett,1983). Similarly, in some South Asian countries' *taro* is also used interchangeably with edible aroids. There is a lot of uncertainty about its name in Asia and the Pacific region (Onwueme, 1999). According to Rahim et al. (2013) plants of six genera of the Araceae family such as *Alocasia*, *Amorphophallus*, *Colocasia*, *Xanthosoma*, *Lasia,* and *Typhonium* are called Taro. Among the genera, two species of *Alocasia* such as *A. macrophylla* (Giant Taro) and *A. fronicata* (Voodoo Lily); two species of *Amorphophallus* such as *A. campanulatus* (Elephant foot yam) and *A. bulbifera* (wild elephant foot yam); two species of *Colocasia* such as *C. esculanta* (true Taro) which composed of two botanical varieties such as *C. esculanta* var. *esculanta* (Eddoe/Elephant-ear/Bamboo taro/ Cocoyam/Dasheen/Chembu) and *C. esculanta* var. *antiquorum* (Wild taro), *C. esculanta* var. esculanta (Mukhi kachu/Thama/Garo thama/Ary kachu); two species of *Xanthosoma* such as *X. atrovirnes* (Tannia) and *X. violaceum* (Blue taro); one species of *Lasia* such as *L. heterophyllas* (Kanta Kachu) and one species of *Typhonium* such as *T. trilobatum* (Bengal arum) are termed as Taro/aroid.

Taro is the common name for the corms, cormels, leaves, petioles i.e., the whole plat and stolons of several genera of the family Araceae. Taro can be found to grow in natural vegetation in all SAARC Member states. In the Maldives, once it was used exclusively as a staple food but later due to crop loss by diseases, taro lost its place as staple food. During the months of food scarcity in Bangladesh, poor people of northern districts used to eat taro as a staple food. Generally, taro is used as vegetable in Bangladesh, India, Nepal, Pakistan, and Sri Lanka. Taro corm and cormels are rich in starch, taro stolons are also rich in minerals and vitamins and leaves are rich in vitamin A. Taro is a major crop in Africa, Caribbean, and Pacific Islands countries where it forms part of the staple diet and serves as an export commodity. It is the most widely cultivated species in these regions

If properly promoted, Taro has the potential to make a much stronger contribution to the development of poor communities, especially in the context of current and emerging global challenges for agriculture caused by climate change, population growth and other factors. Taros are also often more amenable than major crops to cultivate in marginal and degraded agricultural lands, providing opportunities to bring neglected land into cultivation and thereby support greater overall food security. Finally, the promotion of taro is much significant for maintaining biodiversity through sustainable use of local resources.

Taro for Sustainable Nutrition Security

The food habit of South Asian people is predominantly cereal-based. The major portion of diet comes from rice, wheat, and maize, which provide a large share of energy. According to FAO (2017), 50-56 percent of daily energy intake in low- and middle-income countries comes from cereals. Staple cereals provide a relatively low number of micronutrients such as essential vitamins and minerals. Micronutrients support our overall health. Although only small amounts of micronutrients are required by the body, they are essential for maintaining good health. Micronutrient deficiency is difficult to detect and causes severe health problems such as weakening the immune system, stunting physical and intellectual growth, and can even lead to death. As it affects the core health and vitality without feeling emptiness in the stomach it is called "hidden hunger". Hidden hunger imposes a significant burden not only on the affected persons but also on the societies both in terms of health costs and negative impacts in lost human capital and reduced economic productivity. According to Grebmer et al. (2014), all forms of micronutrient deficiency can cut 0.7–2.0 percent gross domestic product in most developing countries. For example, due to micronutrient deficiency in the diet, it was estimated that 1 and 2.3 percent GDP loss in India and Afghanistan, respectively. Global losses in economic productivity due to macronutrient and micronutrient deficiencies reach more than 2 to 3 percent of GDP (World Bank 2006) accounting for US$1.4 to 2.1 trillion per year (FAO 2013). According to FAO (2021), the prevalence of undernourished people in South Asia is decreasing since 2005 (Table 1) but still it is much higher than the world average (8.9%) and the highest in Asia (13.4%). To address these multifaceted problems of malnutrition underutilized crops like taro need to be explored.

The potential of taro to contribute towards food and nutrition security has not been fully exploited in the past mainly because taro has been regarded as an underutilized and minor crop. Farmers benefit by accessing promising local varieties with higher yields and better resilience to climatic factors enabling them to potentially increase their income. The majority of rural people living in remote areas have limited or marginal land to cultivate cereals to meet their food requirements hence has to depend on purchase. Such land can be brought in cultivation with the crop which has higher productivity that can substitute the food requirement. The productivity of taro is much higher (15-20mt/ha) compared to cereals (3-6mt/ha). Likewise, their role in income generation in both domestic and international markets has been also highlighted in several studies and projects (Padulosi et al. 2009).

Table 1. Prevalence of undernourishment (POU) in the world, 2005–2019

Prevalence of Undernourishment (%)							
	2005	**2010**	**2015**	**2016**	**2017**	**2018**	**2019**
World	12.6	9.6	8.9	8.8	8.7	8.9	8.9
Africa	21.0	18.9	18.3	18.5	18.6	18.6	19.1
Asia	14.4	10.1	8.8	8.5	8.4	8.2	8.3
C. Asia	11.0	7.7	3.0	3.0	3.0	3.0	2.7
E. Asia	7.6	3.8	<2.5	<2.5	<2.5	<2.5	<2.5
SE Asia	17.3	11.7	10.5	10.0	9.8	9.8	9.8
Southern Asia	20.6	15.4	14.4	13.8	13.1	13.8	13.4
W. Asia	11.8	10.4	10.7	11.1	11.1	11.2	11.2

Source: (FAO, 2021)

Table 2. Hunger Index Scores in SAARC Countries (GHI, 2020) and Prevalence of undernourishment and food severe insecurity among the total population of three (2017-19) years average

Countries	**GHI score**	**Level of Severity**	**Undernourishment Number in millions (% of total people)**	**Number of severally food insecure people (million)**
Afghanistan	30.3	Severe	11.1 (29.9%)	8.5 (22.7%)
Bangladesh	20.4	Severe	20.9 (13%)	17.2 (10.6%)
Bhutan*	-	-	-	-
India	27.2	Severe	198.2 (14%)	
Maldives*	-	-	-	-
Nepal	19.5	Moderate	1.7 (6.1%)	2.9 (10.3%)
Pakistan	24.6	Severe	26.1 (12.3%)	-
Sri Lanka	16.3	Moderate	1.6 (7.6%)	-

*Bhutan and Maldives could not be included in the 2020 Global Hunger Index because of unavailable data.

Serious Hunger score ranges 20.0-34.9 and moderate 10.0-19.9

Source: https://www.globalhungerindex.org/issues-in-focus/2014.html

Based on the Global Hunger Index (2020) hunger levels of most of the SAARC Countries are severe to moderate. Out of eight, in four countries viz, Afghanistan, Bangladesh, India, and Pakistan levels of hunger are severe. The hunger level in Nepal and Sri Lanka is moderate and data of two other countries such as Bhutan and Maldives were unavailable (Table 2). Increasing dietary diversity is one of the most effective ways to sustainably prevent hunger as well as hidden hunger (Thompson and Amoroso 2010). In the long term, dietary diversification can ensure a healthy diet that contains a balanced and adequate combination of macronutrients (carbohydrates, fats, and protein); essential micronutrients (vitamins and minerals); and other food-based substances such as dietary fiber. One of the effective ways to promote dietary diversity involves the promotion of nutrient-rich underutilized crops.

Taro is regarded as one of the most important staple crops in the Pacific Islands, Asia, and Africa. The dark green leaves of Taro are rich in pro-vitamin A, one of the key micronutrients of public health concern (FAO, 2011). Taro root is rich in complex carbohydrates and is a primary source of starch. Taro's carbohydrates are unique, such as small-sized starch granules, resistant starch type, and have hypoallergenic properties. Several processed products of taro such as taro flour, cookies, noodles are available in several countries. Due to its smaller starch granule, it is easily digestible and used as a major constituent of baby food products.

The nutritional value of major cereals and taro roots is presented in Table 3. Taro roots contain more fiber and most of the essential minerals and vitamins than rice, wheat, and maize in the same amount of energy (200 Kcal). In 200 Kcal energy from each rice, taro, wheat, and maize, taro contains 7% of fiber of Recommended Daily Allowance (RDA). in 200 Kcal of energy from taro provides 11% vitamin C of RDA, 35% of vitamin E, and 46% of vitamin B6 (all critically important for the immune system). The same amount of energy from taro also provides 30%% RDA of Potassium and Manganese, 31% of copper, 26% of Phosphorus, and 16% of Iron (Table 3).

Table 3. Macronutrients and micronutrients content in Rice, Taro (Corm), wheat, and Maize

Components	Rice	Taro	Wheat	Maize
Macronutrients (g)				
protein	4	3	7	5
CHO	43	47	40	41
Fiber	2	7	1	0
Fat	0	0	1	3
Vitamins (%)				
Choline	1	7	1	0
Vit A	0	1	0	0
Vit C	0	11	0	0
Vit E	1	35	2	0
Vit K	0	2	0	0
Vit B1 (Thiamin)	4	17	4	21
Vit B2 (Riboflavin)	2	4	3	10
Vit B3 (Niacin)	5	9	5	17
Vit B5 (Pantothenic acid)	9	11	5	5
Vit B6 (Pyridoxine)	5	46	2	31
Vit B12	0	0	0	0
Mineral (%)				
Sodium	1	1	0	1
Potassium	1	30	2	4
Calcium	1	15	2	1
Magnesium	3	17	4	20
Phosphorus	3	26	9	20
Iron	5	16	8	25
Manganese	23	30	19	12
Selenium	26	3	49	19
Copper	10	31	10	17
Zink	9	4	5	19

Note: in 200 calory, vitamins and mineral units are the percents of recommended daily intake.

Source: USDA Nutrient Database (retrieved in November 2021)

A recent review (Aditika et al., 2021) reported that taro contains a combination of bioactive compounds such as tarin, polysaccharides (TPS1 and TPS2), alkaloids, polyphenols, and saponins, anti-carcinogenic, anti-compulsive, anti-hyperglycemia, anti-hypertensive, anti-inflammatory, hepatoprotective, immunoprotective, and neuroprotective properties.

The documentation of traditional uses of taro food products in rural communities, as well as the quantification of bioactive compounds, demonstrate taro's vast potential as functional food products and in drug development. Hence, screening diverse genotypes for bioactive compounds from different continents could aid breeding efforts directed at taro biofortification. Commercialization of taro usage should be considered as a dietary intervention strategy for addressing malnutrition and hidden hunger in poor communities worldwide.

Increasing dietary diversity is one of the most effective ways to sustainably prevent hidden hunger (Thompson and Amoroso, 2010). Dietary diversity is associated with consuming a diversified diet. In the long term, dietary diversification ensures a healthy diet that contains a balanced and adequate combination of macronutrients (carbohydrates, fats, and protein); essential micronutrients; and other food-based substances such as dietary fiber. Taro is cultivated for its edible corms. Taro is used as a staple food or subsistence food by millions of people in developing countries in Asia, Africa, and Central America. Taro has much importance in ensuring food security, in earning foreign currency as being a cash crop, and also as a means for rural development. Temesgen and Retta (2015) reported that taro contains more than twice the carbohydrate content of potatoes and yield 135 kcal per 100 g. Taro contains about 11% protein on a dry weight basis. This is more than yam, cassava, or sweet potato. Many authors also stated that the protein content of taro is higher than the other root crops in leaves and tuber, respectively. It contains 85-87% starch on a dry matter basis with small granules size of 3-18 μm and other nutrients such as minerals, Vitamin C, thiamin, riboflavin, and niacin better than other cereals. Taro leaves, like higher plants, are rich in protein. The high protein content of the leaves favorably complements the high carbohydrate content of the tubers. In other parts of the world, the leaves of *Colocasia esculenta* have been reported to be rich in nutrients, including minerals such as calcium, phosphorus, iron, and vitamins like vitamin C, thiamine, riboflavin, and niacin. High levels of dietary fiber in taro are also advantageous for their active role in the regulation of intestinal transit, increasing dietary bulk and feces consistency due to their ability to absorb water. Most rural peoples suffer from malnutrition not because of their economic status but because of the inability to utilize the available nutritious raw materials to meet their daily requirements. Nowadays, zinc deficiency is widespread and affects the health and well-being of populations worldwide and since taro is one of the few non-animal sources of zinc, its utilization should therefore be pursued to help in the alleviation of zinc deficiency which is associated with stunting.

Taro for Sustainable Biodiversity

Biodiversity includes the domesticated and the wild relatives of domesticated species. Biodiversity makes production systems and livelihoods more resilient to shocks and stresses, including the effects of climate change. It is a key resource in efforts to increase food production while limiting negative impacts on the environment. It makes multiple contributions to the livelihoods of many people, often reducing the need for food and agricultural producers to rely on costly or environmentally harmful external inputs. Agrobiodiversity is threatened by changing patterns of land use (urbanization, deforestation), agricultural modernization (monocultures and abandoning of traditional, biodiversity-based practices), Westernization of diets and their supply chains. The main problem of dominant monoculture production of plant diversity and associated biodiversity of life cycles in the soil and behavior of the plants.

Current global food security is largely dependent on a handful number of crops because modern agricultural systems promote the cultivation of high-yielding crop species, with the intensification of a limited number of species. This has caused a decline in the cultivation of many locally important traditional crops. This reflects the global trend towards a homogenization of agricultural production and diets leading to monoculture which exacerbates the biodiversity crisis. Moreover, overlooked by research for development efforts many traditional crops lose out in national markets and survive only in small local or niche markets and become 'underutilized' crops such as Taro though it has all the potentialities to be a major crop. Taro along with other underutilized crops is an essential part of natural agrobiodiversity and a rich source of diversified nutrition.

Taro is one of the world's oldest food crops which has been used as food for over 9,000 years (Bioversity, 2015). It can be found in each South Asian country is cultivated as well as in wild forms. it is the most widely cultivated species in the family Araceae which is used as a vegetable in the South Asian region. Taro is widely cultivated, mostly as a staple or subsistence crop, throughout the humid tropics to subtropics, and in many warmer regions of the temperate zone. but now has spread throughout the world and becoming a very important crop in Asia, Pacific, Africa, and the Caribbean. In South Asian countries taro can be found mostly in the backyard as natural vegetation or cultivated in the home garden by women and children or in small land by small-holders. It occupies a significant place in the agriculture of the Asia-Pacific Region. Agricultural biodiversity is crucial to coping with climate change as the entire diversity of genes, species, and ecosystems in agriculture represent the resource base for food (Ortiz, 2011).

Taro or aroids are a highly polymorphic species and one of the most abundant crops in the world, is, cultivated in the humid tropics and sub-tropics. However, according to Mathews and Ghanem (2021) taro is widely distributed in tropical to temperate regions in both hemispheres. The present distribution of taro (*Colocasia esculenta*), as a cultivated food plant, extends from southern to northern Africa, western Asia to eastern Asia, throughout Southeast Asia and the Pacific Islands, and through the Americas, from the USA to Brazil (Matthews, 2006).

it is widely cultivated for its leaves, corms, and petioles which are consumed as vegetables. Taro is native to Southeast Asia and Southern India, but it is widely neutralized as it is spread by cultivation to other parts of the world. It grows in paddy fields with abundant water or upland areas with sufficient rainfall or supplemental irrigation. Flooded cultivation of the crop yields a higher harvest as compared to dry-land farming. Underutilized crops are better adapted to marginal soil, complex and difficult environmental conditions (climate change, which will have an impact on biotic and abiotic stress), and they can contribute significantly to the diversification and resilience of the agroecosystems.

Food-based solutions that diversify what we grow and what we eat provide enduring benefits to local communities and the environment by addressing these problems at their base. The world needs to continue securing the production of staple crops to feed the world, but that effort must be complemented by parallel investments in the many nutritious and resilient crops. Diversifying the production systems with the injection of various underutilized crops will buffer food systems against socio-economic shocks and at the same time strengthen the health of agroecosystems, support smallholder agriculture, safeguard food cultures and associated economies that revolve around local crops and traditions now fast disappearing. In addition, taro/aroids are drought-resilient, so they hold the potential to tackle negative climate change impacts.

Taro is better adapted to marginal soil, complex and difficult environmental conditions (climate change, which will have an impact on biotic and abiotic stress), and they can contribute significantly to diversification and resilience of agroecosystems (Powell et al., 2015). Geographically, taro can be found to grow spanning latitudes from 35°N to 35°S occupying an extensive latitudinal range (a total of approximatively 70°) and extents wetland to dry land, so is dispersed in the hydrological dimension as well (Matthews and Ghanem, 2021). In South Asia, it is found to grow in diverse ecological conditions where other crops may find it difficult or adverse, such as, mild to high hill areas where land is unsuitable to grow cereals even if can grow rice and wheat production is significantly low. Taro also can grow marshy and waterlogged conditions. In rural areas of southern Bangladesh, taro can be found to grow abundantly in marshy lands. Some Taro cultivars can tolerate salinity and can be found to grow in 25-50% seawater, such saline conditions would prove lethal to most other crops. Partially shady conditions are unique places to grow taro and can grow well as an intercrop between tree crops (e.g., coconuts), because it can profitably exploit the diffuse light).

Rich agricultural biodiversity represents a robust agricultural production system with the capacity to withstand future changes such as climate change. Underutilized crops are an important component of biodiversity (Dawson et al., 2007) which provide special genetic traits and contribute to enhancing the diversification and resilience of agroecosystems to withstand the impacts of climate change scenarios. Unfortunately, due to overemphasis on a few crops several nutritionally rich, environmentally safe, and wide adaptable species are overlooked and sometimes disappear from the field because of their scarce competitiveness in modern agriculture.

Role of Taro in Economic Development

Poverty Alleviation: Although taro has been neglected and underused, they hold great potential: hardy and highly nutritious, can form a universe of tastes and flavors, higher productivity than many other crops, Fallow and uncultivable land can be brought under cultivation, export potential and can fetch foreign currency by exporting. The productivity of taro is higher than rice. In an experiment Jaganathan et al., 2020) reported that the average yield of taro (43.34 quintal/ acre) was higher than the yield of paddy (20.94 quintal/ acre) but the production cost was not much different in respect of the cost of production. Net profit from taro cultivation was significantly higher than rice cultivation, thus, taro cultivation is more profitable. On average, the taro growers realized 128 percent higher net returns than the paddy growers (Jaganathan, et al., 2020).

Women empowerment: Taro is a vegetatively propagated crop. For mass propagation, a low-cost tissue culture technique can be used which is the best-suited work for women. Women can be involved in harvesting and post-harvest handling of Aroids. This can be empowered women and meet the demand for labor.

Export Potentials: Taro has a big export market in the USA, Canada, Japan, and Middle Eastern countries. South Asian countries should explore the opportunities for commercial production of taro.

Pharmaceutical use: Sudhakar et al., (2020) reviewed the pharmaceutical use of taro and reported that two pharmacologically active compounds, Flavonoids, and Triterpenoids are present in the leaf extracts of Colocasia which showed Antimicrobial, Antifungal, Antidiabetic, Hepatoprotective, Anthelmintic, Anti-inflammatory, Anti-Melanogesnic, Antioxidant, Antimetastatic, Neuropharmacological, Hypolipidaemic and Estrogenic activity in vitro and some in Vivo conditions.

Alternative fuel: Biofuel is an alternative source of reducing the use of fossil fuel. Many countries have been using taro for producing biofuel to reduce the crisis of fossil fuel and greenhouse gas effects. For example, in 2017, a group of students in the Philippines used wild taro for producing biofuel. Praputri and Sundari (2019) also used wild taro for biofuel production and Wei-HaoWuet et al. (2015) used waste of taro for producing biofuel.

World Bank (2007) commented that underutilized species may provide alternative sources of biofuels, that can be produced in more efficient ways than the methods currently employed, which frequently have low economic viability and carry high social and environmental risks

Taro is a source of income generation: Taro production generates income for several subsistence farmers in both West Africa and the Pacific. Taro contributes significantly to poverty alleviation for several vulnerable groups in producing regions. For some Pacific countries, taro exports form a substantial part of foreign exchange earnings.

Industrial use: Taro starch is incorporating food industry for the preparation of baby food, supplementary food for the elderly, and people with the compromised digestive system because of the small size of the taro starch granules which is easily digestible. It has been used in the preparation of baby food in Hawaii and the Pacific islands. The very small size of taro starch granules makes them ideal for cosmetic formulations such as face powder and for dusting preparations that use aerosol dispensing systems. Harold et al. 2000) reviewed on uses of taro and reported that taro can be used in ten types of processed foods: (1) taro paste, (2) taro flour, (3) cereals, bread, and cake, (4) beverage powder, (5) taro flakes, (6) taro slices, (7) taro meal (8) canned taro, (9) frozen taro, and (10) extruded food. Industrial uses are mainly fillers or modifiers for plastics.

Global Scenario of Taro

Globally 10, 542, 001 tons of taro production was recorded in 2019 (FAOSTAT, 2021). Africa is the height taro-producing country (72%), followed by Asia (23%), Oceania (4%), and America (Figure 1). According to FAO (FAOSTAT, 2021) globally among the leading ten taro-producing countries, seven are in Africa, two countries are in Asia and one country is in Oceania (Papua New Guinea), No country in America is in the top ten producing countries.

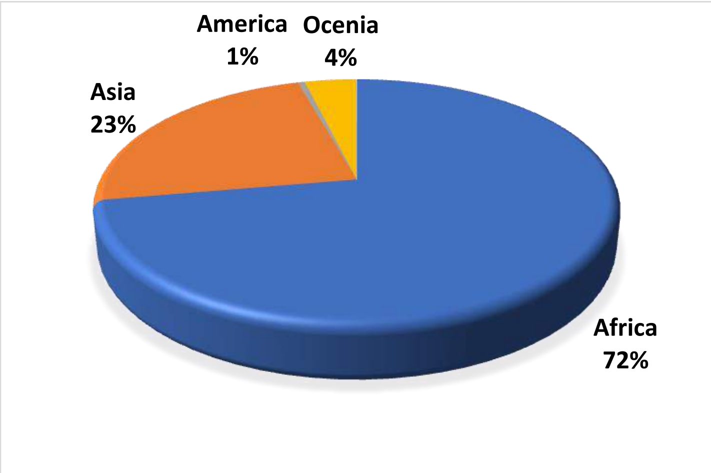

Figure 1. Region-wise taro production in 2019 (FAOSTAT, 2021)

Globally Nigeria is the highest producer of taro with about 2.86 million tones which is 27.14% production share of world total production in 2019 followed by Cameroon, Ghana, Madagascar, Burundi, Rwanda, and central Africa. Among Asian countries, China occupied the third position and Loas occupied the ninth position in respect of global taro-producing countries Papua New Guinea is the only country in Oceania regions that occupied the 5th position in 2019 (FAO, 2021).

Table 5. Global top 10 taro producing countries in 2019

Country	Production (tons)	Global production (%)
Nigeria	2,860,909	27.14
Cameroon	1,909,738	18.12
China (mainland)	1,908,830	18.11
Ghana	1,518,436	14.40
Papua New Guinea	271,981	2.58
Madagascar	226,438	2.15
Burundi	217,570	2.06
Rwanda	171, 830	1.63

Country	Production (tons)	Global production (%)
Lao People's Republic	154,644	1.47
Central Africa	140,957	1.34
Rest of the world	1,160, 668	11.0
Total	10,542,001	100

Source: FAOSTAT, 2021

Globally, the top ten importing (A) and exporting (B) countries of taro in 2020 are presented in Table 4. North America is the top importer of taro, for instance, in 2020, the United States imported 40.44 percent of the total taro imports Table 6 A). Among the top ten taro importing countries five countries, such as Japan, UAE, Vietnam, Saudi Arabia, and Malaysia are in Asia. Which are the good neighbors of the South Asian region. Currently, China is the top exporting country of taro and particularly exporting to other Asian countries (Figure 2). In 2021 China exported USD 78.52 M which is 46.98 percent of the global export share (Table 6 B).

Table 6. Top ten importing (A) and exporting (B) countries of taro in 2020

Country	Import value (USD in millions)	Share in import value (%)
USA	64.96	40.44
Japan	45.61	28.4
Australia	9	5.6
New Zealand	7.93	4.94
Canada	3.67	2.28
Netherlands	3.5	2.18
UAE	3.49	2.18
Vietnam	3.43	2.14
Saudi Arabia	3.4	2.12
Malaysia	2.51	1.56

(* Global total import Value in 2021 was 160.61M)

Top ten exporting (B)

Country	Import value (USD in millions)	Share in import value (%)
China	78.52	46.98
Ecuador	37.22	22.27
Fiji	15.69	9.39
Costa Rica	8.68	5.19
Nicaragua	4.35	2.6

Country	Import value (USD in millions)	Share in import value (%)
Indonesia	3.08	1.84
Honduras	2.82	1.69
Samoa	2.6	1.56
Netherlands	2.34	1.4
USA	1.99	1.19

(Global total export $ Value in 2021 was 167.12M)

Due to the good quality of starch content in taro corms and a good quantity of vitamins and minerals in leave and corms, the demand for taro is increasing across the globe. In this situation, there is a huge scope of South Asia to enter neighboring East Asian region and Middle Eastern countries. Rising demand from North America, Japan, and other countries also indicates that globally there is a big market of taro in developed countries. Hence, new markets in Europe and the United States of America could be explored by the region to substitute other rapidly perishable vegetables as taro is convenient to transport.

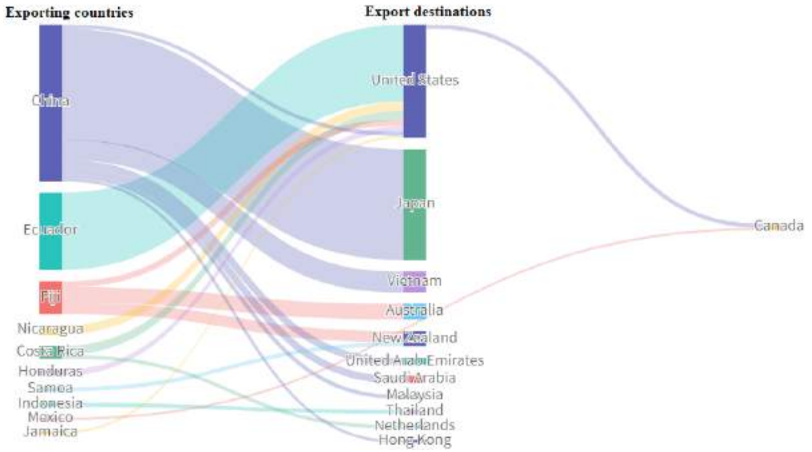

Figure 2. Global export channel of Taro (Adapted from Tridge, 2021)

Taro in SAARC Countries

During the consultation meeting, an interactive session was conducted through a set of questions (Annex 1). A questionnaire was provided to all the participants to know the real situation of taro in their respective countries. Compilation of participants' responses is furnished below. Detailed information on taro can be found in the respective country chapter in this book.

Bangladesh

Taro is still an underutilized crop in Bangladesh though people are aware of its Nutritional contribution. It is mainly used as vegetable. Different parts such as leaf, petiole, corm, and flower of upland taro (Mukhi kachu) while stolon and rhizome of low land taro (Pani kachu) are consumed. Taro is gaining popularity in recent past years It plays a vital role in the lean period (September to November) while other vegetables are in shortage in Bangladesh. Around 80% of people know that it is a good source of vitamin A and iron, while total nutritive values are yet unknown among the rural people. In Bangladesh, taro is known as "Kachu". Tuber crops Research Centre of Bangladesh Agricultural Research Institute has been conducting a limited extent of research on taro and developed a few good quality verities, and production packages. Limited commercial cultivation also started with the developed varieties for local consumption and export to overseas ethnic markets. Land under taro cultivation has increased more than 50% in the past two decades and consequently total production and yield have increased. taro. Considering the available fallow lands, growing conditions, and research work on taro, Bangladesh could start commercial cultivation of taro targeting the export market and can earn foreign currency by exporting both fresh and processed taro. But no attempt has been taken to use taro in processing and use in a bakery or other food industries.

Bhutan

Taro is completely an underutilized crop in Bhutan and people are not aware of its nutritional value as food. Currently, it is only grown in a small area of the backyard gardens of some farmers for home consumption and livestock feed. It is not a priority crop and hence, no research and development works have been undertaken by the government or any private organizations. Therefore, Bhutanese people are not aware of its medicinal and industrial values. Taro species are important in the southern parts of the country, although small patches can be found throughout Bhutan. Taro can be found Widespread and can grow up to 500-3000 altitude.

India

Taro is not an underutilized crop in India. It is very well utilized as a vegetable across India. The entire quantity of taro produced in India is either consumed domestically or sold in the market. It fetches good consumer prices comparable to other tropical tuber crops. However, some people may dislike its mucilage and slimy texture. Sometimes, improper cooking/processing may not eliminate acridity resulting in an itching sensation in the mouth. This may lead to the disliking of the consumption of taro.

Although its potential medicinal value has been established in mice models, its utility for human remains is to be clinically proven and medicinal values are yet to be commercialized. The utilization of taro starch for industrial purposes as well as for drug delivery is yet to be upscaled. Further, the utility of taro for value-added products like chips, bakeries, etc., is yet to be upscaled. People are aware of its nutritive value based on indigenous traditional knowledge. However, people are not aware of its real scientifically analyzed nutrient composition. This is because the proximate composition of taro is published in Scientific journals. To bring it to the common people popular articles in newspapers, magazines and folklores could be helpful. Market players (processing industry, bakery, pharmaceuticals) and policymakers (export policy, etc.) are not aware of its industrial values. Presently, taro is used mostly as vegetable. Value-added products, medicinal values, utility in drug industries have been realized but not yet upscaled. Maybe, the market players are either not aware of the utility of taro for industrial purposes, bakery pharmaceuticals as information on these have been generated during recent years or it could be due to cost competitiveness.

Maldives

To some extent, taro is not an underutilized crop in the Maldives. Once taro was part of staple food in the Maldives. After the introduction of rice and wheat, they lost their place as a staple food. There is a demand for the processed product of taro such as taro chips in tourists' areas. Recently Taro Leaf Blight is becoming a threat to taro production in the Maldives. compared to the cash crops taro is still an underutilized crop, the income from taro is not as lucrative as other cash crops, so farmers' investment in this crop is less. Since traditionally taro is grown in marshy/swampy areas, the dry-land cultivation of this crop is not common. From the government side lot of emphasis is given to promoting this crop in all its food security-related programs. Still needs further exploitation of the crop and diversifying the product range. But Government plans and policies for the development of variety, cultivation technology, and its dissemination have not been focused as compared to other crops.

Nepal

Taro is an underutilized crop in Nepal. It is not a part of their staple food. Habitually, most of the Nepalese population depend on rice as it is their staple food and they take taro as a supplement of vegetable. Farmers are not taking it as a major crop, they used to plant in marginal land where other crops don't perform well, and even, they do not bother if the crops do not perform better.

Have Supplied food for a very limited period: Harvesting is done in November and corms are used to be eaten for only 2 months though, dried forms of leaves, petiole, and even corms are used as vegetables but as supplementary.

Research and Development work have been just started: Plan and policy for the development of variety, cultivation technology, and its dissemination have not been focused as compared to other crops.

People occasionally take it as supplementary vegetable but not as regular dietary parts. If other vegetables are not available or they want to change the taste of vegetables, they take taro as vegetable. Nepalese people are not giving importance to taro. People don't like to consume taro regularly even if it is available, they search for another taste. Some people take it in as breakfast/ rarely as a staple during harvesting season. (saying "only poor man consumes it as a staple food"). Not much aware of the nutritive value of Taro. None of the above-mentioned market players are fully aware of the industrial use of taro. They either have no awareness or have no confidence in the supply of raw materials for their purpose.

Pakistan

Taro is also an underutilized crop in Pakistan. There is little awareness about the nutritive value of taro. The current area under taro cultivation is very small. Taro corms are used as vegetables in some areas of Pakistan but the use of taro leaves as a vegetable is rare in Pakistan suggests that there is a need to generate awareness. Taro has not been a priority for the processing industry, bakery, and pharmaceuticals. Again, this is a potential area that needs to be explored. Taro variety development is a potential area that has to be explored. Varietal variation has not been studied in much detail except for a recent genetic study. Taro can be grown in shaded and submerged conditions, so it can be grown under existing plantations and can potentially be grown in waterlogged areas. As shared by an expert from other SAARC countries particularly Bangladesh and Maldives that it grows in waterlogged conditions.

Sri Lanka

In Sri Lanka, *Colocasia esculeata* is an underutilized crop but *Xanthosoma spp* is cultivated on a commercial scale. *Colocasia esculeata* is only cultivated in the home gardens of the low and middle wet zones of the country. The unavailability of quality planting materials is a major problem. This crop has not yet been identified as a priority crop in Sri Lanka. In the country's agricultural statistics, taros/aroids are included in the other root and tuber crops group, no separate data are available. Sri Lankan taro/aroids can be harvested after compared to the other root and tuber crops less land extent is cultivated. Unawareness among the younger generation. No agronomic package was developed for the crop. Limited research has been conducted in Sri Lanka. There are some varieties of aroids, such as one variety, named "Isuru" of *Xanthosoma spp,* and two varieties, Gaja" and "Dimuthu" of *Colocasia esculenta*, there are several local accessions are in their collections. In 2019 Taro chips have been introduced in the Sri Lankan market. A small number of aroids are also exporting from Sri Lanka.

Local names of taro in South Asian countries and its current status of use including edible parts and scope of increased production have been presented in Table 7.

Table 7. Local names and edible parts of Taro in South Asian countries

Country	Local names	Status	Edible part	Scope
Afghanistan	Kachalo Pashmk	Very neglected	Rarely corm and cormels	Huge fallow land can be brought under cultivation
Bangladesh	Kachu	Underutilized, no commercial or industrial production	All parts	There is a scope to target middle eastern countries for exporting
Bhutan	*Dowoh* (in Dzongkha, national language) and *Peyralu* (in Lhotshamkha,	Very neglected	Rarely used as a food	Huge fallow land can be brought under cultivation

Country	Local names	Status	Edible part	Scope
	(Southern Boardedlanders)			
India	Arbi, Chaembu, Shaeppamkizhangu, or Ghuiyaa	utilized	All parts	Vegetables, Commercial and industrial production
Maldives	Ala	Once it was the staple food crop but not getting proper importance	Corm and cormels	Production can be increased for local consumption
Nepal	Corm: *pindalu* petioles with leaves: *karkalo/Gava*	Underutilized, not commercially grown	all parts	Fallow lands, hill slopes can be brought under taro cultivation
Pakistan	Arvi, Arbi, Kachaloo/ Kachalu',	Under-utilized has potential	Green leaves, mother corm, new/daughter corm	Huge fallow land can be brought
Sri Lanka	Kiri Ala	Under-utilized/ Not commercially grown	Corms and leaves	There are about 163,562 Ac of fallow paddy lands. Therefore, these lands can be utilized for the cultivation of taro

Challenges

- Limited knowledge and awareness of the nutritional, medicinal, and commercial value of Taro. To bring it to the common people, popular articles in newspapers, magazines, and folklores could be helpful. Market players (processing industry, bakery, pharmaceuticals) and policymakers (export policy, etc.) are not aware of its industrial values.

- Long duration crop. It is difficult to fit in a cropping pattern (2-3 crops) in a unit of land within a year
- Unavailability of quality planting materials is a major problem. Cormel are used as propagule. Cormel production rate is slow.
- It is not a priority crop nor the farmer or the government. Less strategic options for an increase in Taro production. less land under cultivation. Lack of private sectors interest
- Lack of high-yielding varieties. Limited or not research initiatives
- Lack of information and knowledge regarding the crop production technology
- No proper local and foreign market channel identified
- Unawareness among the younger generation. There is little awareness about the nutritive value of taro
- Numerous viral diseases are known to attack taro species. They are the most serious viral pathogens with some infections resulting in severe yield reductions and even plant death. The most common worldwide is the Dasheen mosaic virus (DsMV) which is spread by aphids. It is characterized by chlorotic and feathery mosaic patterns on the leaf, distortion of leaves, and stunted plant growth. Taro bacilliform virus (TaBV) is transmitted by the plant hopper, Colocasia bobone disease virus (CBDV) is a cytorhabdovirus.
- Fungal diseases like are taro soft rot, are caused by several species of Pythium, which is soil-borne and attack the roots and corm. Sclerotium rot is caused by Sclerotium rolfsii, which causes stunting of the plant, rotting of the corm, and formation of numerous spherical sclerotia in the corm. Cladosporium leaf spot is caused by Cladosporium Colocasia where brown spots appear on the older leaves.

Recommendations

Germplasm collection and evaluation: It is required to collect, evaluate, characterize local germplasm for identifying promising varieties and breeding materials; need to conserve local germplasm.

Variety development: Research should be taken to develop Insect-pest and stress resistance/ tolerant varieties, for example, leaf blight-resistant varieties need to develop by using conventional and biotechnological techniques. It is also required to develop suitable varieties for processing and industrial uses.

Production technology: Identifications of location-specific production technologies suiting diverse agro-climatic conditions.

Seed multiplication: Initiative should be considered to establish taro seed villages/ techno-incubation centers for multiplying high yielding varieties engaging rural women and youth using tissue culture techniques; Agriculture Departments, Farmers Producing Organizations (FPOs), and entrepreneurs also need to be involved.

Post-harvest management and technology: it is required to enhance and facilitate research on the postharvest handling, processing, and value-added products of taro such as chips, fresh-cut vegetables (Rhizome and Shoot), etc.

Awareness and capacity development: Campaign on utilization of fallow and marginal lands, engage small farmers on taro production and utilization needs to undertake; promote to develop awareness to involve youth and women in seed sector; encourage people to consume organic as a safe and nutritious food; the potential utility of taro starch in pharmaceutical and food industries needs to be popularized; capacity of farmers, researchers, entrepreneur, youth and women need to be developed as required.

Commercialization: Need to Initiate commercialization of Taro for food security and industrial use; establish farmers' cooperative societies for assisting farmers in marketing and value addition; need to study external demands for Taro products such as Taro flour and powder; encourage private sectors for opening industries along with the commercialization of the produces; pharmacological properties of taro have been understood at the laboratory level, its effect on a human yet to be established through clinical trials.

Research facilities and infrastructure development: it is required to establish a separate research division on root and tuber crops, including taro, and invest in taro production infrastructure development; government should develop the farm as a practical training resource center for field-level technicians, cooperatives/farmers to transfer modern production and post-harvest technology. also need to develop well-equipped research centers and export production zones.

Extension and local coordination: Need to strengthen coordination/linkages among researchers, academicians, extensionists, and development practitioners by one chain of command of the Central; need to develop expert team consisting of Breeder, Plant Protection specialist, Soil and Crop Nutrition specialist, post-harvest and marketing specialist, etc. for promoting taro; need to develop and manage Taro crop horticulture technicians/extension service providers at ward level who can provide embedded service to the clients.

Regional cooperation: It is suggested to exchange of unique germplasm/ varieties among SAARC countries for mutual benefits; needs to initiate and collaborative research for improving taro research in partnership with regional research institutes among SAARC countries; should strengthen collaboration and linkages with other regional/international organizations for germplasm sharing and capacity development.

The importance of integrated action for the promotion

Jaenicke and Hoschle Zeledon, (2006) reported that the International Centre for Underutilized Crops (ICUC) and the Global Facilitation Unit for Underutilized Species recognized the following five key intervention areas for realizing the potential of underutilized plants:

1. Improving production through characterizing genetic resources, by genetically enhancing species, through devising effective strategies for maintaining diversity to sustain productivity, by developing better germplasm delivery systems and crop management procedures, and by improving methods for post-harvest handling.
2. Communicating knowledge better among stakeholders by disseminating successful promotion stories, through lobbying of policymakers, by more targeted media campaigns, and through the continued development of education curricula that promote underutilized plants.
3. Enhancing policies that remove barriers to production and marketing, through initiating dialogue on the benefits of underutilized crops, promoting access to markets locally and globally, and through better protecting farmers' intellectual property rights to local knowledge on taxa.
4. Facilitating market development through increased entrepreneurial training, fostering more public-private partnerships, promoting access to credit and grants for marginalized stakeholders, and carrying out more market surveys on preferences, risks, and compatibilities.
5. Promoting better partnerships among all stakeholders, through encouraging strategic alliances on underutilized species, promoting multidisciplinary research teams, and by strengthening relationships among all participants in value chains.

Conclusion

Taro is rich in starch, fiber, vitamins, and minerals with enormous health benefits though it has not been fully explored in South Asian countries yet. There is a huge potential to promote taro in South Asian countries for food and nutrition security as taro can be found to grow in natural vegetation and marginal soil, complex and challenging environments conditions which is difficult to grow rice and other cereal crops. Each South Asian country has fallow lands which can be brought under taro cultivation with location-specific varieties. But need to develop an awareness of consumers, producers, and policymakers for its nutritional, commercial, and industrial values. As it is still an underutilized crop in the South Asian region except for India, there are several challenges to promoting taro. Hence it is of utmost importance to undertake research on taro to address the current challenges. In developing countries like the USA, Japan Taro starch is being used in the food and pharmaceutical industries. The huge trade potentials in taro's international market can be explored. Diversified climatic conditions, considerable fallow lands, and local landraces can be appropriate to grow taro commercially in South Asian countries. Likewise, their role in income generation in both domestic and international markets need to explore.

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Chapter 2

Status of Taro in Afghanistan

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Abstract

In Afghanistan, taro (*Colocasia esculenta)* has several traditional cultivars distributed in some parts of the country. In Afghanistan agriculture, root and tuber crops, including taro, can play a major role in maintaining biodiversity. The threats to food security in Afghanistan are poverty, malnutrition, and unsustainable practices, and climate change. Decreasing food security and increasing poverty resulted from several factors. Taro is among the crops neglected. Taro has good nutritional qualities and broader commendations of vitamins and minerals compared to other root and tuber crops.

Introduction

Afghanistan is a landlocked country with an area of 652225 sq km. it has a mountainous landscape. One of its famous mountains with the longest ranges is the Hindu Kush. This mountain range covers a major part of the country. The average elevation of its peaks from the sea level is about 3000 m. However, the highest peak of Safed Koh (mountains rang in eastern Afghanistan, which expands into Khyber Pakhtunkhwa, Pakistan) reaches an elevation of more than 6000 m from the sea level. One-sixth of the country's landscape is comprised of deserts. The Northern parts of Hindi Kush with an elevation of 300-400 m form most of the flat surface in this area. Over 80% of the country's water resource has its origin in the Hindu Kush Mountain. It functions as a natural water reservoir, storing snow during winter and supporting perennial flows in all the major rivers during summer by snowmelt. In the Southeast of the country, there is a vast desert called Marji, joining the Lota deserts of Iran to the west side of the country.

The climate of the country is continental and subtropical. The Marji desert of the Southwest and the desert of the Northern parts continuing to the banks of the Amu River has a sub-tropical climate, while the remaining areas of the country have a continental climate.

Topography is considered to be one of the factors, affecting the climate of Afghanistan. The southeastern parts of the country which are influenced by the Indian monsoon support dense vegetation of Oak and conifers forests. The rainfall happens during the winter and spring seasons, often in form of snow and rain. The total annual precipitation of the major parts of the country is less than 300 mm.

By 2018-19 the total population was estimated to be 31.6 million, of which 1.5 million are nomads.

Out of the total land area of the country (64 million hectares), about 12 percent of the total land area is arable land, from which 5.6 percent (3.6 million hectares) is irrigated agriculture land, 5.8 percent (3.7 million hectares) is rain-fed agriculture land, and the remaining are either fruit trees, vineyards, or marginal agricultural land. Forests (open and closed natural needle-leaved forests) and high shrubs land make up 2.8 percent (1.7 million hectares) of the total area of the country. Afghanistan's rangeland, 30.2 million hectares or 47 percent of the total land is grassland, forbs, and or low shrubs.

Taro as Vegetable: Production Area and Uses

Vegetables are mostly grown for market and home consumption. An estimated 11.6 percent of the total irrigated land was planted with vegetables, the total area under potato cultivation was 32.4 thousand hectares while its production was 615.7 thousand tons, and potato yield was 19 tons per hectare. Potato and onion are major vegetables; they are particularly used as food in the country. The area under onion cultivation in 2018 was 10551 hectares.

The Taro, locally known as Kachalo Pashmk is produced in some parts of the country especially in Nangarhar province by local farmers. The areas dedicated to taro in Afghanistan by local farmers appear very small compared to the total area of the country. Similarly, the per capita consumption of taro in Afghanistan is smaller than that of any of south Asian countries. It is not surprising that taro is a relatively neglected crop in Afghan agriculture.

Taro: Its Biodiversity and Sustainability

Afghanistan is rich in biodiversity and the government recognizes the importance of conserving it. The goods and services provided by biodiversity support the livelihood basis for the majority of the Afghan population. About 80 percent of Afghan's livelihood is either directly or indirectly related to the tangible goods and services that biodiversity provides. The direct use of the components within bio diversities such as traditional crops, fruits, grazing, fuel, timber, harvesting, fishing, and hunting are key to the Afghan rural population. In addition, ecosystem services such as soil fertility, erosion control, crop pollination, and climate stability are also crucial to the agriculture and food security of the country. Taro crop is a key component of biodiversity. Biodiversity's command is to advance the protection and use of plant genetic resources for being of present and future generations. Biodiversity concentrations on preservation and use of genetic resources important to developing countries.

Role of Taro in Nutrition Security

Food insecurity and malnutrition are some of the most serious manifestations of protracted crisis as they disrupt livelihoods and markets. Afghans have lived through foreign intervention, civil war, insurgency, and widespread insecurity for decades, severely disrupting Afghanistan's economic growth trajectory.

Over half of the Afghan population, approximately 16 million people live below the poverty line in 2016-17 a sharp increase over the last decade. Food insecurity has increased in line with poverty and 13 million Afghans (45 percent of the population) are food insecure. Of these, an estimated 3.9 million are very severely, 4.1 million severely and 5.0 million are moderately food insecure with a larger number and proportion of the rural population affected by food insecurity. Changing climatic conditions, a growing population, and other environmental stressors will likely have a significant impact on food security going forward.

The predominant causes of food and nutrition insecurity in Afghanistan are multifold: limited food production and availability of food supplies, climate change, insufficient access to food due to widespread poverty, food shortages arising from disasters or price shocks, poor diets, poor health, water and sanitation conditions as well as insufficient knowledge of nutrition issues which prevent proper food utilization and others.

Through several policies, strategies, and programs, the Government of the Islamic Republic of Afghanistan has expressed its commitment to enhancing food and nutrition security for the Afghan people.

Taro (*Colocasia esculenta* Schott) is a highly nutritious crop that plays a critical role in ensuring food and nutrition security, especially in Afghanistan. Taro corm is an excellent source of carbohydrate, the majority being starch of which 17-28% is amylase, and the remainder is amylopectin. Taro is good for people to have allergic to cereals and can be consumed by children who are sensitive to milk. Taro protein content is slightly higher than the sweet potato. The protein is rich in some essential amino acids. Taro leaves are rich in nutrients including minerals and vitamins such as calcium, phosphorous, vitamin C, iron, riboflavin, thiamine, niacin, etc.

Challenges and Prospects of Taro in Afghanistan

Afghanistan has unlimited potential for the production of vegetable crops especially taro due to different climate conditions favorable soils and an industrious and abundant workforce. However, the potential for increased taro supply and international marketing cannot be realized unless capacity is improved through better field production and management methods. Although this contributes a complex array of challenges, the Taro production system is extremely low in comparison to other root and tuber crops due to a lack of planting materials. Lacking improved and high-yielding varieties is the main challenge in Afghanistan for the promotion of taro. Pest and diseases affect largely taro productivity which becomes a limiting factor for taro production. No taro research and extension work were done in Afghanistan because there is no basic research conducted on the agriculture of Afghanistan. Only adaptive and applied research is conducted mostly on cereal crops. No modern varieties of taro have been developed yet. The lack of modern vegetable cold storage and packing facilities has severely limited producer access to anything other than local markets in Afghanistan. Moreover, people are not aware of the nutritional and economic potential of taro.

Recommendations and Conclusion

It is recommended that the research institute of Afghanistan undertake research on the new variety development of taro. The three-decade war created a lot of problems in Afghanistan, especially in the horticulture sector. The regional responsibilities are to help these countries to improve the taro production system in Afghanistan.

In conclusion, there are many suggestions put forward to focus on taro crop research and improvement to meets the needs of the ever-increasing rapid Afghan population. First, there is a need to protect the genetic diversity of the species. There should be sufficient information on the ecological distribution of the taro and safeguarding its indigenous local knowledge. Secondly, there is a need to develop taro crop innovation systems to be strengthened and made more participatory to improve adaptability, productivity, adoption rates and enhance food and nutrition security of small and low resources farmers. This result will generate innovations to enhance crop adaptability to the consequences of climate change, crop diversification, and productivity constraints. Thirdly, the government should develop the basic policy framework on agronomic practices for underutilized crops like taro to ensure commercial production of this particular crop for food sustainability to address poverty, malnutrition, and income generation of local farmers.

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Chapter 3

Present Status and Prospects of Aroids in Bangladesh

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Abstract

Aroids or Taro are an important food crop throughout the world under the family Araceae. Out of 110 genera of the Araceae family, only five genera are edible. These are *Colocasia*, *Amorphophallus*, Xanthosoma, Alocasia, and *Cyrtosperma*. Those are collectively called Aroids or Taro. Among five genera, the first four genera are cultivated in Bangladesh. The whole plant viz. leaf, petiole, corm, cormel, rhizome, flower, etc. are edible parts. Aroids have a higher nutritive value than other root and tuber crops. It contains highly digestible starch, protein, minerals, and vitamins. Aroids have some medicinal values. It is also highly recommended in diabetic patients for its blood sugar-reducing ability. Aroids are hardy plants that grow various types of soil and unfavorable climatic conditions. It is also called a famine crop. In Bangladesh, *Colocasia* (Mukhikachu, Panikachu, Panchamukhi kachu, Poidnal kachu) are dominated for commercial cultivation whereas *Amorphophallus* (Elephant Foot Yam) occupied the 2nd position in respect of cultivation. Aroids are fulfilled the major portion of the demand for vegetables during the rainy and autumn seasons. Meanwhile, Bangladesh Agricultural Research Institute (BARI) has been released 11 Aroids varieties from three genera of the Araceae family. Among them, some varieties are gaining more popularity by the farmers and consumers. Different cultural management techniques such as optimum time of planting, planting geometry, doses of manure and fertilizers, irrigation scheduling, weeding, disease, insect pest control, and corm storage method are developed by the researchers. These high-yielding and acrid-free varieties and management practices of the production technologies are playing a vital role for boost aroids production and maintaining the food and nutritional security of the people in Bangladesh.

Introduction

Taro or Aroids are known as "Kachu" in Bengali language. In respect of nomenclature in Bengali language especially for varietal classification, a word is added as prefix before "Kachu". for example, Mukhikachu, Panikachu, Panchamukhikachu, Sahebikachu, Olkachu etc. Aroids or Taro are an important food crop throughout the world under the family Araceae. Out of 110 genera of Araceae family, only 5 genera are edible. These are *Colocasia*, *Amorphophallus*, *Xanthosoma*, *Alocasia* and *Cyrtosperma*. Those are collectively called Aroids or Taro. Among five genera, the first four genera are cultivated in Bangladesh. The origin of *Colocasia* is in south-east Asia regions, probably India, Bangladesh, Myanmar and Indonesia (Matthews, 2004). This genus is cultivated widely in the world (FAO, 2018). Taro is domesticated and cultivated by at least 10,000 B.C (Fullagar et al., 2006). It stands the 9th position among world food crops. Taro tubers are important sources of carbohydrates and are used as staple foods in tropical and subtropical countries (Rashmi *et. al*., 2018). At present in Bangladesh, Aroids occupied 30.92 thousand hectares of land and produced 280.52 thousand metric tonnes with an average yield of 9.07 t/ha in 2018-19 (BBS, 2020). In the last 20 years, the area, production, and yield were increased under aroids cultivation around 58%, 100% and 26.5%, respectively (Fig. 1). From the figure, it revealed that the consumption of aroids has increased considerably by the people of Bangladesh in the last two decades.

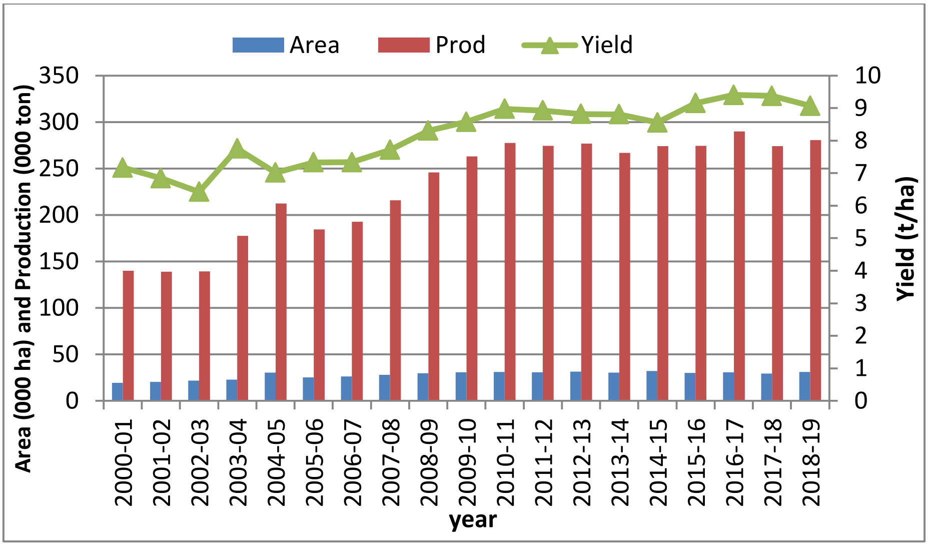

Fig. 1 Area, Production and yield of Aroids in Bangladesh

Nutritional value

Aroids are rich in digestible carbohydrates containing 70-80% starch on a dry basis. It is highly digestible because of the small size starch granule (3-18 μm). Taro tubers supply one-third energy of an equivalent weight of rice or wheat (Rashmi et. al., 2018). The leaves and corm are nutritious food. Taro leaves contain starch, minerals and vitamin A, B-complex and C (Sheth, 2005). Its corm contains carbohydrates, dietary fibre, fat, calcium, phosphorus, readily available iron, Zinc, vitamin A, C, thiamine, riboflavin and niacin (Jirarart et. al., 2006).

Medicinal value

Aroids have some medicinal values. Taro starch is also good for peptic ulcer patients, patients with a pancreatic disease, chronic liver problems and inflammatory bowel disease and gall bladder disease (Emmanuel-Ikpeme et al., 2007). Miller (1971) stated that the babies who were fed a baby food prepared from taro were found to suffer less from some diseases like diarrhea, pneumonia, enteritis and beriberi than babies fed with rice and wheat. It is used to maintain normal bowel movement in case of constipation, intestinal heat and others. It is said to be very effective in lowering cholesterol levels. It also relieves arterial blockage and vein blockage. It is highly recommended in diabetic patients for its blood sugar-reducing capability. Ayurvedic medicine system uses it in the treatment of emesis, dysmenorrhea, fatigue, constipation, piles, dyspepsia rheumatism and others (Prajapati et al., 2020). Elephant foot yam is also useful in maintaining healthy hormonal levels in the body. The glycemic index (GI) of corm was estimated 63.1 ± 2.5 indicates aroids corm as a medium GI food and a good dietary carbohydrate source for diabetic people (Simsek et al., 2015).

Weather and Climate

All cultivable Taros are grown under almost similar climatic conditions. All the aroids like hot and humid climate. The suitable temperature is 25-40^{0}C (Rashid, 1993). Generally, we know that aroids are shade-loving but it is not fully true. Because, when Dasheen (Mukhikachu) and Panikachu are grown in full sunny condition, they produced higher yield along with better quality (corm, stolon and rhizome).

Commonly cultivated varieties

In Bangladesh, mainly two types of *Colocasia* viz. *Colocasia esculenta* var. *esculenta* (Dasheen, in Bengali language it is called as Mukhikachu) and

Colocasia esculenta var. *stolonefer* (Bengali name is Panikachu) and *Amorphophoallus paeoniifolius* (Elephant foot yam, bengali name is Olkachu) are widely cultivated as the commercial basis. Mukhikachu is an upland crop because it can't stand stagnant water. Only Panikcahu can tolerate some stagnant water among the edible aroids in Bangladesh. Panikachu comprises two types based on stolon (in bengali it is called Lati) production. Panikachu which produces mainly stolon called a stolon producing Panikachu. Its main commercial product is stolon along with small to medium size rhizome. Another type is called rhizome producing Paninkachu which produces mainly rhizome along with less stolon production. Other aroids like *Alocasia* (Giant taro, in bengali Maankachu or Fankachu), *Xanthosoma violaceum* (in Bengali it is called Dudkachu). *Xanthosoma undipes* (in bengali its name is Sahebikachu or Moulovikachu) are mostly domesticated in the niche of homestead area, besides roads and rail lines and they occupied the very small area under commercial cultivation. Under the species of *Colocasia esculenta*, two local cultivars namely Panchamukhi kachu and Poidnal kachu are commercially cultivated in some areas like Modhupur in Tangail district and little in hilly areas. Besides, leaves (only leaf petiole and leaf lamina) of *Colocasia* are used as green vegetables and called, Kachu shak or shak-kachu. It grows naturally. It is comprised of green and purple stems. These are also grown in marshy homestead areas, besides canals, ponds, riverbanks etc.

Edible parts

Edible parts of aroids in Bangladesh are corms, cormels and leaves of Mukhi kachu, for Pani kachu stolon, rhizomes and young shoots, for Ol kachu main corm, leaf and matured rhizome for Maankachu/ Fankachu and Sahebi kachu/ Mooulovi kachu and leaf for Dud kachu.

In general, Aroids are neglected crop in Bangladesh but their use is diversified and consumed by all classes of people both in rural and urban areas. The lean period of vegetable production in Bangladesh is the rainy to autumn seasons (July to mid-November). In that time aroids mitigate the majority part of the demand for vegetables.

Present status of research

Yet, little attention has been paid to aroids research in Bangladesh by Tuber Crops Research Center, (TCRC) under Bangladesh Agricultural Research Institute (BARI). In 1988, BARI released one Mukhi kachu and one Pani kachu variety. The next variety was released in 2008. Aroids research activities are limited as more emphasis is given the major/main vegetables of potato than a sweet potato. Agricultural Universities of Bangladesh also address as less important regarding aroids research work. As a result, all the aroids are not yet under advanced research. At TCRC, BARI, major research works are going on Mukhi kachu and Pani kchu and a little bit on Ol kachu and the others.

Developed varieties of Aroids/Taro

Bangladesh Agricultural Research Institute (BARI) has released 11 Aroids varieties from three genera of Araceae family. These are stated in the below table.

Table 1. Name of varieties of aroids in Bangladesh

Sl. No.	Genus	English/Bengali Name	Name of Variety	Released Year
1	*Colocasia*	Panikachu	**A. Stolon Producing**	
			1.BARI Panikachu-1 (Latiraj)	1988
			2. BARI Panikachu-2	2008
			B. Rhizome Producing	
			3. BARI Panikachu-3	2008
			4. BARI Panikachu-4	2013
			5. BARI Panikachu-5	2013
			6. BARI Panikachu-6	2017
		Dasheen (Mukhikachu)	1. BARI Mukhikachu-1 (Bilasi)	1988
			2. BARI Mukhikachu-2	2013
2	*Amorphophallus*	Elephant Foot Yam/ Olkachu	1. BARI Olkachu-1	2018
			2. BARI Olkachu-2	2018
3	*Xanthosoma*	Sahebikachu	1. BARI Sahebikachu-1	2020

Characteristics of Aroids varieties

Varieties of Panikachu

BARI Panikachu-1 (Latiraj)

- Stolon is the main part of economic production.
- Presence of red mark at the adjacent of leaf blade and stalk.
- The length of the stolon is about 1 meter.
- There is a bending at the base portion of the stolon.
- Color of stolon: slightly purple.
- Acridity-free and boiled homogenously.
- The life span is 210-270 days.
- Yield (t/ha): Stolon 25-30 and Rhizome 15-18

BARI Panikachu-2

- Stolon is the main economical production part.
- Leaf-sheath and leaf blade are deep green.
- The length of the stolon is about 1 meter.
- The Color of the stolon is deep green.
- Acridity-free and boiled homogenously.
- The life span is 210-270 days.
- Yield (t/ha): Stolon 25-30 and Rhizome 15-20

BARI Panikachu-3

- The rhizome is the main economical production part.
- Stolon production is medium
- It is produced dual-purpose (medium yield for both rhizome and stolon).
- The color of the base of the leaf sheath is medium purple.
- Acridity-free and boiled homogenously.
- The life span is 210-240 days.
- Yield (t/ha): Rhizome 25-30 and Stolon 10-15

BARI Panikachu-4

- The rhizome is the main economic production part.
- The color of the leaf sheath is deep purple.
- The color of the rhizome is medium purple.
- The flesh of the rhizome is slightly purple.
- Acridity-free and boiled homogenously.
- The life span is 210-240 days.
- Yield (t/ha): Rhizome 35-45 and Stolon 5-8

BARI Panikachu-5

- The rhizome is the main economical production part.
- The color of the leaf sheath is green.
- The color of the rhizome is slightly greenish.
- The flesh of the rhizome is white.
- Acridity-free and boiled homogenously.
- Acridity-free and boiled homogenously.
- The life span is 210-240 days.
- Yield (t/ha): Rhizome 35-40 and Stolon 5-8

BARI Panikachu-6

- The rhizome is the main economical production part.
- Black spots are present in between veins of the leaf blade. In matured leaves, black spots become pale.
- The color of the leaf sheath is green.
- The color of the rhizome is green.
- The flesh of the rhizome is white.
- Acridity-free and boiled homogenously.
- Life span is 210-240 days

Yield (t/ha): Rhizome 60-80 and Stolon 5-8

Varieties of Mukhikachu

BARI Mukhikachu-1 (Bilasi)

- The corm is smooth and oval.
- The color of the corm is bright brown.
- The flesh of the corm is white.
- The plant is green, erect, and medium in height
- Corms and cormels are easily boiled homogenously and have no acridity.
- The life span is 225-270 days.
- Yield (t/ha): 25-30

BARI Mukhikachu-2

- Corms are smooth and oval.
- The color of the corm is blackish brown.
- The flesh color of the corm is white.
- The plant is green, erect, and medium in height.
- Corms and cormels are easily boiled homogenously and showed no acridity.
- The life span is 225-270 days.
- Yield (t/ha): 25-30

Varieties of Olkachu

BARI Olkachu-1

- The color of the upper surface of corm flesh is purple.
- The average number of cormels per corm is 3-3.5.
- Flesh color is orange and carotene-rich.
- Individual corm weight is 2-5 kg.

Corm yield (t/ha): 45-55

BARI Olkachu-2

- The color of the upper surface of corm flesh is slightly purple.
- The average number of cormels per corm is 8-9.
- The flesh color is yellow.
- Individual corm weight is 1-3 kg.
- Corm yield (t/ha): 35-45

Varieties of Sahebikachu

BARI Sahebikachu -1

- Commercially harvestable stage of rhizome starts after 2 years and continued up to 5 years.
- Acridity-free and boiled homogenously.
- The edible portion is 92%.
- The rhizome can be stored at ambient temperature for up to 2 months (approximately).

- Individual rhizome weight is 25-35 kg (after 3 years) and 50-60 kg (after 5 years)
- Yield (t/ha): 60-90

Cultivation Techniques of Panikachu

Soil and climate: Panikchu are usually a plain land crop. Panikachu grows well in soil that is always in wet condition. Panikchu can sustain waterlogged conditions but growth becomes stunted in waterlogged conditions. Surface water at the base of the plant should be running up to 10 cm for commercial cultivation. Organic rich loam and clay loam soils are suitable for Panikchu cultivation. Panikachu should be cultivated in sunny places all day long. Panikchu is a *Kharif* season crop but the optimum planting time is *rabi*. This crop needs a warm and humid climate. The crop grows well at 25-40°C temperature.

Planting time: Mid-December to mid-January is the best time to plant seedlings (sucker) to get commercially profitable crops. If you want to do an early harvest, you can plant from mid-October also.

Planting distance (Spacing) and seed rate: Row to row distance should be 60 cm and seedling to seedling distance should be 45 cm. If seedlings are planted at the above-mentioned spacing, 37037 seedlings (sucker) per hectare will be required. Alam et al. (2011a) observed that three months old seedlings required 72 days for the first harvestable stolon whereas one-month-old seedlings required 102 days under the plant spacing of 60 cm × 45 cm. The maximum number of stolons per plant (23) and stolon yield (20.91 t/ha) was obtained with the variety of BARI Panikachu-1 (Latiraj) under the same cultivation condition.

Manures and fertilizers

Table 2. Doses of manure and fertilizers for Panikachu

Name of manure & fertilizers	Amount (kg/ha)
Cow dung or compost	10000 - 15000
Urea	300-350
Triple superphosphate (TSP)	150-200
Muriate of potash (MOP)	300-340
Gypsum	100-130
Zinc sulfate	10-15
Boric acid	10-12

The total amount of cow dung, TSP, gypsum, zinc sulfate, boric acid and half MOP fertilizers should be applied at the time of final land preparation. One-fifth of urea is applied after 15-20 days of planting. The remaining MOP and one-fifth of urea should be applied after 40-50 days after planting as the second top dress. The rest of the urea should be applied thrice equally in the same manner after 15–20-day intervals from the second top dressed.

Irrigation: Necessary irrigation should be given after top-dressing the fertilizers in the soil. In addition, the amount and timing of irrigation will depend on available soil moisture. Appropriate measures have to be taken for the drainage of water during the rainy season.

Weeding: The cropland should be kept free from weeds especially the first 3-4 months is very crucial for weed control.

Harvesting: Initial (first emerge) stolon (Lati) should be harvested when the stolon attained 10-15 cm long. After that, the periodic harvest of stolon should be done before the stolon emerges seedling. The rhizome should be harvested when the plant growth is stunted and the leaf becomes shortened.

Cultivation method of Mukhikachu (Dasheen)

Land preparation: The land should be cultivated well in joe condition and the soil should be loosened by 3-4 cross plowing followed by laddering.

Planting time: February is the best time to plant seeds (corm) to get commercially profitable crops. If you want to do an early harvest, you can plant from mid-December.

Spacing and seed rate: Row to row distance should be 60 cm and seed to seed distance should be 35 cm. If seeds are planted at the above-mentioned distance, 300-500 kg of seed (corm) per hectare will be required.

Manures and fertilizers

Table 3. Doses of manures and fertilizers for Mukhikachu

Name of manure & fertilizers	Amount (kg/ha)
Cow dung or compost	10000 - 15000
Urea	250-300
Triple superphosphate (TSP)	125-175
Muriate of potash (MOP)	250-280
Gypsum	100-130
Zinc sulfate	10-15
Boric acid	10-12

The total amount of cow dung, TSP, gypsum, zinc sulfate, boric acid, and half of MOP and one-fourth of urea should be applied at the time of final land preparation. After loosening the soil with the spade, half of the remaining urea and the rest of MOP should be applied in a row at 40-50 days at the base of the plant. The remaining urea should be applied in the same manner at 90-100 days after planting. Earthing up should be done just after top dressed. Alam et al. (2011b) observed that the highest yield (21.91 t/ha) was obtained following the practices of no desuckering and two earthing up at 45 and 90 days after planting in the variety of Mukhikachu of BARI Mukhikachu-1 (Bilasi).

Irrigation: Necessary irrigation should be given after applying the top-dressed fertilizers. In addition, the amount and timing of irrigation will depend on available soil moisture. Appropriate measures have to be taken for the drainage of water during the rainy season.

Weeding: The cropland should be kept free from weeds especially the first 3-4 months is very crucial for wed control.

Harvesting: If 2/1 of the Mukhikchu leaves become yellow and died, it is a good time to harvest the corm/cormels. It usually takes 8-9 months from planting. Corms should be harvested earlier (1/2 months ago) even get reduced.

Corm Preservation: Corm (in Bengali Mukhi) preservation should be done when corm/cormels are harvested at fully matured conditions. After collecting the corm, it is necessary for curing in a shady, dry and ventilated place for 2-3 weeks. At that time the good, healthy corms/cormels should be sorted. The corms/cormels should be spread in a cool, dry and well-ventilated place in the house. However, the water loss is high in this method of storing. It should be stored on the floor upon a layer of dry sand (10 cm), then corm should be spread over the sand (20-30 cm), then again make a layer of dry sand (10 cm), and this way 5-6 layers of corms/cormels should be kept and finally make a layer of sand (10 cm) on top. This way it can be easily stored for 4-5 months. This method reduces water loss to some extent.

Intercropping of Mukhikachu

As Mukhikachu is a long-duration tuber crop, corm/cormel harvesting is comparatively late than many other vegetables. As a result, farmers get income from a single crop after 7 to 9 months of planting but they can earn some money from cultivating short-duration vegetables as intercropped with Mukhikachu. Without yield reduction of the main crop, the short-duration vegetable was grown as a component crop like red amaranth, Stem amaranth, Lady's finger, Indian spinach, etc. in between two rows of Mukhikachu. Alam et al. (2011c) revealed that Mukhikachu intercropped with Stem amaranth is more profitable. Since stem amaranth can be harvested fully within 60 to 70 days after sowing, it was found low competition with Mukhikachu consequently the yield of Mukhikachu was not affected by any means. Suitable plant spacing is 60 cm × 45 cm for Mukhikachu and 30 cm × 10 cm for Stem amaranth when both crops were cultivated as intercropped systems. Seeds of Stem amaranth should be sown continuously in a shallow furrow of 15 cm apart from the first row of Mukhikachu then 30 cm apart another shallow furrow should be made and seed sowing accordingly. Likewise, two rows of stem amaranth could be cultivated in between two rows of Mukhikachu as an intercropping system. After 15 to 20 days, thinning will be done for Stem amaranth by maintaining a 10 cm plant to plant distance. Fertilizer's rate is urea 300-350 kg/ha, TSP 150-200 kg/ha, MOP 250-300 kg/ha, Zinc sulphate 12-15 kg/ha, Boric acid 10-12 kg/ha and cow dung 10-15 t/ha. The total amount of cow dung, TSP, Zinc sulfate, Boric acid and half of the MOP will be applied at the time of final land preparation. Half of the urea will be applied by side dressing of Mukhikachu and Stem amaranth after thinning of Stem amaranth. Rest Urea and MOP will be top dressed by side-dressing after harvesting of Stem amaranth followed by earthing up. Irrigation should be done after top dressing urea and/ MOP. The yield was obtained 23-25 t/ha and 24-28 t/ha from Mukhikachu and Stem amaranth, respectively. This way the benefit-cost ratio was found 2.84 :1 while as sole Mukhikachu the benefit-cost ratio was found 1.90 :1.

Stem amaranth intercropped with Mukhikachu

Cultivation procedure of Olkachu (Elephant foot yam)

Land selection and preparation: Well-drained organic materials rich in clay loam, sandy loam soils are suitable. Excess clay and sandy soil are not suitable for cultivation. When the soil is in "joe" condition, the land should be plowed followed by a ladder for 3-4 times as cross-system depends on soil types.

Seed making: Corms that are usually developed after one/two years of planting in different sizes of cormels are used as seeds for commercial production. In this case, the seeds are developed by the planting of the small-sized cormels for one year.

Time of planting: February is the best time for planting. It can be planted up to mid-April. Late planting reduces the yield.

Planting distance (Spacing): It is not possible to determine a single distance for Olakchu like other crops. Seeds (Corm) of different sizes need to be sown at different distances.

Table 4. Spacing for seed and commercial production of Olkachu

Seed (corm) size (g)		**Planting distance (cm)**	
For seed production	For commercial production	For seed production	For commercial production
50	400-600	50 cm × 40 cm	60 cm× 50 cm
50-200	600-800	60 cm × 45 cm	60 cm× 60 cm
200-400	800-1000	60 cm× 50 cm	75 cm× 75 cm

Planting method: For commercial production, holes have to be made at a specified spacing. The size of the hole will be slightly larger than the diameter of the seed. Depth will be three times higher than the height of the seed corm. However, the shape of the hole varies depending on the seed size.

Manure and fertilizers

Table 5. Doses of manures and fertilizers for Olkachu

Name of manure & fertilizers	Amount of fertilizers (kg/ha)
Urea	325
Triple superphosphate (TSP)	210
Muriate of potash (MOP)	175
cow dung/compost	20

Half of the TSP, MOP, and cow dung should be applied during final land preparation. The remaining half of this manure and fertilizers should be applied to the sowing hole. Urea should be applied in two equal 2 installments at 50-60 and 100-110 days after planting, respectively in the ring method.

Weeding: Hand weeding should be done at 50-65 days after planting for the first time and the second time at 100-115 days after planting. The land should be kept free from weeds during the cropping period.

Irrigation: Irrigation should be given just after planting if there is less soil moisture and no rainfall. Make light drains after every two rows or sides of each row so that rainwater can drain out easily.

Mulching: Covering (mulch) with rice straw, wheat straw or water hyacinth which can increase the yield many folds and weed infestation will be reduced. Some studies revealed that 70-75% yield was increased by using different mulching.

Harvesting: Up to 2-4 pseudo stems are seen emerging from one tuber. The old one died after a new pseudo stem comes out. When 80% of the plants in the field become yellow, the crop becomes mature and the crop can be harvested at that time. For seed production, the crop should be harvested after the plant dried completely.

Diseases and their control measures

Leaf blight

Causal organism: *Phytophthora colocasiae*

Symptoms

- The symptoms on leaves are small, dark brown flecks or light brown spots on the upper leaf surface.
- These early spots often occur at the tips and margins of leaves where water accumulates. The spots enlarge rapidly, becoming circular, zonate, and purplish-brown to brown in color.
- On the lower leaf surface, spots have a water-soaked or dry gray appearance and hard globules of plant exudate are sometimes present. In severe conditions whole leaf rotted and withered.

Control measures

- Use of disease-free healthy planting materials
- Field sanitation, removal & destruction of infected leaves.
- Adjustment of planting date to escape disease infestation.
- Intercropping with the non-host crop.
- After noticed the symptoms, spray fungicides of mancozeb group (Dithane M-45) / Fluazinam group (Secure)/ Mancozeb + Metalaxyl group (Ridomyl Gold) @ 0.2% at 15 days interval.

- Spray fungicides of Propiconazole group Tilt 250 EC @ 0.1% at 10-15 days interval.
- Irrigation and drainage should be maintained properly during spraying for disease control.

Leaf spot

Causal organism : *Colletotrichum capsicii* or *C. lindemuthianum*

Symptoms

- Small dark round spots appeared on the upper leaf surface and coalesce together.
- Sometimes, came out yellow ooze and later on it became purple in color.
- In severe conditions the whole leaf becomes rotted and withered.

Control measures

- Collect healthy vigorous seedlings /corms from a disease-free place
- It can be controlled by spraying Tilt (0.5 ml/liter) 2-3 times at an interval of 10-15 days.
- This disease can be reduced by adopting clean cultivation.

Foot /collar rot

Causal organism: *Sclerotium rolfsii*

Symptoms

- In the attack of this disease, white mycelium is seen at the base of the plant. A closer look reveals a dark brown mustard-like sclerosing structure.
- The affected plant turns completely yellow and eventually falls off the collar region.
- In a severe attack of the disease, the underground corm is damaged and the whole plant falls.

Control measures

- Seeds should be collected from disease-free fields or areas.
- The water should be removed from the field and sprayed with Carbendazim group (Bavistin) @ 1 g/liter of water at an interval of 10-15 days after noticing the disease symptoms. However, after spraying fungicides, it will be better to wait at least a day then water can be given again.
- After harvesting, crop residues must be removed or burned.
- This disease can be reduced by adopting clean cultivation.

Rhizome rot/Corm rot

Causal organism : *Pythium aphanidermatum*

Symptoms

- The attack of this disease stops the growth of young plants, even the plant may die.
- In older plants, the leaf turns yellow and stops growing, consequently, the whole plant falls.
- In severe attacks of the corm become rots, it is not even possible to collect any corm from the Mukhikachu field.

Control measures

- Seedlings/corms should be collected and planted from disease-free fields or areas.
- Clean cultivation, crop rotation must be followed.
- After harvesting, crop residues must be destroyed.
- After showing disease symptoms, the cropland should be drained out and then spray with Ridomyl Gold (2 g/liter) in the base of plant and surrounding soil.

Insect pest and its control measures

Taro caterpillar/Prodenia caterpillar: *Spodoptera litura* Fabricius

Nature of damage

These insects usually eat leaves or green parts of plants. The adult caterpillars quickly eat the entire green part of the leaf, causing all leaves to turn brown and the leaves become dry out. Many times the plant dies. In addition, this insect also attacks stolon.

Control measures

- Collecting and destroying eggs and destroying insect-infested leaves by hand
- Using pheromone traps. It is possible to attack and kill male insects to get pheromone traps. This will prevent the emergence of new insects and will gradually reduce the number of insects.
- The insects can be easily controlled by applying the biopesticide SNPV (Spodoptera Nuclear Polyhydrosis Virus) with pheromone traps.
- If the infestation of this insect becomes high, Tracer 45 SC should be mixed @ 0.4 ml per liter of water and sprayed 2-3 times. If the infestation is severe, this insect can be controlled by spraying Quinolphus group insecticide (Deviquin 25 EC/Kinalax 25 EC) in 1 ml per liter of water.

Red Mite : *Tetranychus urticae* Kochu

Nature of damage

Attack of red mites can be seen on the lower side of the leaves. Generally, those cannot be seen with the naked eye. Both adults and nymphs damage the plant. Red mites usually attack the lower side of the leaves and suck the sap, resulting in yellowish spots appearing on the leaves. The leaf becomes shrinks when severe attack noticed in the lower part of the middle portion of the leaf. Extreme attack results in yellowing and browning of the entire leaf and eventually the leaf becomes dried.

Control measures

- Mite infestation is more prevalent in dry weather conditions and less in heavy rains.
- Mites can be controlled by mixing 1.5 ml of Abamactin group (Vertimec 1.6 EC) per liter of water with water at 10-15 days intervals for 2-3 times.
- One kg of half-broken neem seeds should be soaked in 10 liters of water for 12 hours and sprayed on both sides especially on lower side of the leaves or mixed with 5 ml of neem oil + 2 ml of Tricks (liquid detergent) per liter of water and sprayed 3-4 times in 10 days interval.

Constraints

- Aroids are long-duration crops. Crop durations for vegetable and seed production of different aroids are stated below.

Table 5. Crop duration for vegetable and seed production

Name of crop	**Duration (months) for**	
	vegetable production	**seed production**
Dasheen (Mukhikachu)	8-10	10-11
Elephant foot yam (Olkachu)		
Panikachu (rhizome producing)	7-8	10-15
Panikachu (stolon producing)	7-10	10-15

- It is difficult to fit in a cropping pattern (2-3 crops) in a piece of land within a year.
- It is more difficult to increase cropping intensity through aroids cultivation/incorporation/inclusion.
- Aroids are very much sensitive positively to organic manure, but at present, the availability of organic manure is very much scanty for farmers in Bangladesh.
- To ensure the availability of seed is difficult due to its less seed multiplication rate.
- GOs, NGOs and private organizations are not producing and selling their seed (corm, sucker/seedlings).
- Nowadays, Prodenia caterpillar and leaf blight are becoming threats for aroids cultivation in Bangladesh.

Prospects

- Develop resistant or tolerant variety against leaf blight disease and Prodenia caterpillar through biotechnological intervention.
- Develop technology for the fresh-cut vegetable of Panikachu (Rhizome, Stolon and Shoot).
- Develop technology for aroids processed products and their marketing.
- Varietal improvement of aroids through hybridization, biotechnological approaches can play a vital role in the commercial production of taro.
- Seed multiplication is required through the Tissue culture approach for promoting taro cultivation in the future.
- Enhance and facilitate research on post-harvest handling, processing and value addition.

Conclusion

Many starches enriched root and tuber crops are cultivated throughout the world especially in tropical and subtropical regions for their use as vegetables. Aroids are used as one of the staple root and tuber crops or subsistence food in some regions of Asia and the Pacific. Aroids are not only very nutritious food crops but also have many health benefits (medicinal value) such as anticancer activity, phenolic acid, phytochemicals, etc. Aroids can be grown as a carbohydrate-rich crop, as a leafy vegetable, as an ornamental, and as a medicinal plant as well. As a hardy plant, it can grow in adverse conditions (both of soil and climatic) and may serve nutritious food for the human being. That's why it is also called a famine crop. Though the negligence attitude is prevailing in research and farmers are very much reluctant for the cultivation of Aroids in Bangladesh. However, Aroids are gaining popularity as vegetables by all classes of people in both rural and urban areas in Bangladesh.

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Chapter 4

Status of Taro in Bhutan

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Abstract

Taro (*Colocasia esculenta*) in Bhutan is grown as backyard gardens by the farmers in the southern foothills and lower mid-altitude regions of elevation ranging from 200-2500 masl. except for settlements in the northern temperate regions. This crop having huge therapeutic medicinal value can be explored and investigated further to be utilized for the treatment of some common illnesses besides helping the people to secure food. As the plant has been studied for different pharmacological purposes like analgesic, anti-inflammatory, anti-cancer, anti-diarrheal, astringent, nervine tonic, and hypolipidemic activity, it is necessary to exploit it to its greatest potential in the therapeutic and pharmaceutical field. Consumer education on taro cultivation, nutritional values and health benefits could increase taro production. More research and examination will enhance and improve the understanding and contributions to crop and offer in the fields of food security, health wellbeing and economic empowerment. It is felt essential to initiate and start a cross-country study on genetic diversity of taro, crop suitability, and different methods of cultivation for crop improvement and conservation and value addition. The establishment of a research network of taro genetic resources and cross-border technology transfer across the SAARC countries and beyond would be extremely useful. The SAARC agriculture center can play a pivotal role in fund support and coordinating as a regional program in the region.

Keywords: Colocasia esculenta, nutritional security, medicinal value, technology transfer

Introduction

The mountainous country, Bhutan is nestled between India and China. It has an area of 38,394 square kilometers (Gilani H, 2015) The elevation ranges from 200 to > 7,000 meters above mean sea level. About 95% of the country's area is mountainous terrain. Bhutan is broadly divided into three geographic areas and corresponding climatic zones; the southern foothills, inner

Himalayas, and higher Himalayas. It has six distinct agro-ecological zones. The climate is dominated by the monsoon with a dry winter and high precipitation during June-September. The wide climatic condition is influenced by topography, elevation and rainfall patterns. Bhutan has a diverse altitude ranging from <650 to >5,500 meters above sea level. In these diverse agro-ecological zones, crops such as rice, maize, wheat, barley, buckwheat, millets, mustard, potato, citrus and vegetables are grown as the main crop besides rearing livestock for livelihood.

The cultivated agricultural land constitutes only 2.93% (112,556.21 Ha) and the forest coverage with 70.46 % of the total land area accounts for its rich biodiversity with a high level of species, genetic and ecosystem diversity (LCAR, 2010). Agriculture continues to dominate the country's economic activities and gives employment to almost 62.2 % of the population out of 727,145 (PHCB, 2017). Cereals are an important component of the Bhutanese diet where rice and maize are the major crops cultivated in Bhutan. Other cultivated crops include wheat, barley, buckwheat, millets, oilseeds, legumes, vegetables, apple, mandarin, cardamom, tubers, rhizomes and corms. Among the corms, Taro (*Colocasia esculenta*) is grown in backyard gardens by the farmers both for human consumption and livestock feeds.

Taro in Bhutan

Colocasia esculenta (L) Schott, (Family: Araceae) is an annual herbaceous plant grown widely in the tropical and subtropical regions and is a nutrient-rich crop (Ghosh et al., 1988). Locally, it is called *Dowoh* in Dzongkha (National Language) and *Peyralu* in Lhotshamkha in Bhutan. This crop was supposed to be first domesticated in Southeast Asia, has continued to spread throughout the globe (Rao, 2010). In Bhutan Taro is grown almost all over the country except in northern temperate areas. Most of it is grown in the southern foothills and mid-altitude areas at an elevation ranging from 200-2500 masl. Taro represents an important source of vitamins and minerals especially folic acid. As stated by Matthews (2010), Taro in many cultures is a sacred plant with high respect and culturally strong and symbolic importance. The early history of Taro cultivation in Bhutan is vague since there has been very little documentation done in the past in a localized area. Unlike other crops, Taro crop has remained neglected as not much research and development has taken place thereby lacking concrete documentation on its distribution, cropped area and production.

Nevertheless, we can find cultivation of this crop being done at the backyard level only by almost all the households in the foothills and mid-altitude regions. In rural Bhutan, farmers still recognize the importance of this crop in all aspects of their lives even to this day, particularly in terms of meeting their dietary needs and mostly for livestock feeding.

Production

In rural areas in Bhutan, Taro has played a significant role in maintaining household needs both for human consumption and animal feeds. The crop is grown commonly as warm-season crop requiring annual average rainfall between 1200 – 1400 mm (Ngawang, Personal Communication, 7 October 2020). This crop is mostly grown as rain-fed in dry land under good soil moisture and partial shade conditions frequently intercropped under fruit trees. It thrives best in loamy soil with sufficient organic matter and adequate soil moisture content. Land preparation is done a few weeks before with one plowing operation. Irrigation is hardly a supplement except during long drought periods and late rainfall. Planting is normally done at the onset of the spring season i.e., from March to April months. Planting is done in ridges usually 70-80 cm apart and plants to plant spacing of 50-60 cm. Manures and fertilizers are applied during the time of initial land preparation. Mulching is done immediately after planting to retain soil moisture and reduce weed pressure. Taro in backyard farming communities is mostly rain-fed and they hardly supplement irrigation except during long drought and dry spell periods and late rainfall (as per personal communication with the backyard farmer growers; Mr. Thinley, Mr. Ganga, Mr. Ram, Mr. Tenzin, and Mr. Ghalley on 7 October 2020).

Backyard taro plants are normally harvested manually within 130-150 days after planting or when the leaves starting yellow. The harvested corms are cleaned and separated from main (mother) corms. The corms and tender shoots (pseudo stem) are used for their home consumption only. Only corms that are separated from the mother tubers are used as seed for the next season. The tuber seeds are stored in the cold room.

Varieties

There are many species of *Colocasia* seen both in wild and domesticated. The vast majority of the cultivars used in ornamental gardens belong to *Colocasia esculenta*. There are also a small number of ornamental varieties known by the species such as *Colocasia affinis, Colocasia fallax, Coloca siagigantea*, and *Coloca siaheterochroma* which are inedible are available for garden beautification. There are few edible local cultivars of *Colocasia* grown in different parts of Bhutan such as Bo-dzong (Hatipailay), Langkay, Bhadanray and Chilawnay. These varieties are not identified taxonomically as research and development work on Taro is not done yet.

Uses

Nothing much written about this crop from different disciplinary perspectives on its distribution in the specific locations and areas in Bhutan. Although Taro is a vital staple food crop and fodder crop in the tropics as is grown as food crop elsewhere in the countries like India, China, Southeast Asia, Indonesia, Polynesia, the Mediterranean, Africa, and South America, this crop in Bhutan has not gained national importance so far. It is known that all parts of the plant are edible if they are thoroughly steamed or boiled to first remove calcium oxalate crystals. Beginning the 20th century, agricultural scientists started to preserve the *Colocasia* varieties and started the breeding works. In Bhutan, corms of Taro are eaten after boiling and also as porridge and curries. The tender leaves (pseudo stems) are eaten as a vegetable. Tender petioles and stolons are preserved and used in pickling. Also, the tender blades and petioles of leaves are dried and preserved for consumption during the times of less or no vegetables in winter. Besides human consumption, the leaves and stems of the plants are used as feed for livestock, particularly for piggery farming.

Taro for Biodiversity and Sustainability

In Bhutan, the importance of biodiversity is accentuated by the country's unique social, cultural, economic and physiographic conditions. The country can be dubbed as a conservation centerpiece of the Eastern Himalayas, a region known to be one of the global biodiversity hotspots. Despite being a small country, it is home to 5,603 species of vascular plants, 677 species of birds and nearly 200 species of mammals. In terms of domestic biodiversity, there are more than 80 species of agricultural crops and 15 species of livestock. Some of these have adapted to the country's rugged mountain and harsh climatic conditions and, therefore, bear distinctive features. The country carries enormous regional and global conservation significance. As a consequence, the country presents a unique opportunity for foresighted action for conservation and sustainable use of biodiversity rather than post-damage restoration which many countries around the world are currently struggling with. For the Taro crop, there are few accessions grown scatter or sporadic in the backyards of farming communities residing in mid and low agro-climatic zones. Taro plants are multiplied and cultivated through vegetative propagation. As of now, there has been less attention towards the cultivation, promotion, and conservation of Taro in Bhutan. Considering the prospects of these crops and the present use of the crop by farmers for food and livestock feed, this crop is enlisted in the National Bio-diversity action plan.

Role of Taro in Nutrition Security

The Bhutanese culture, food habits and agriculture practices were no doubt influenced by those prevailing in the neighboring regions, especially Tibet, Arunachal Pradesh, Assam and West Bengal. Yet, most of the Bhutanese communities evolved with some degree of isolation resulting in specific food habits. Traditionally, food from the wild, either from the forest or from the fallow vegetation of *tseri* fields, were important food source, especially for the rural communities. These plants included wild yam species, taro and ferns.

It is known that Taro plant has high nutritional value even though the crops are neglected and less importance driven. Kaur (2018) mentioned that the taro crop is very rich in dietary fiber which plays an important role in the treatment of diseases like obesity, diabetes, gastrointestinal disorders and even cancer. Despite its high medicinal value, people in Bhutan have not popularized this crop as a priority food like other vegetables. For instance, chili *(Capsicum annum)* is a very important ingredient for all Bhutanese cuisine that no dishes are cooked without chili (Roder et al., 2008; Choden, 2007).

Because of its medicinal value and nutritionally rich food as compared to other root and tuber crops, this crop plays a vital role in food security as it has low-fat content, rich in protein, minerals, and vitamin contents (Kaur and Sepat, 2018). Baruah (2002) also reported that Taro leaves have been reported to be rich in nutrients and minerals such as calcium, phosphorous, iron and vitamin C, thiamine, riboflavin, and niacin. Given the multi-benefits of this crop, behavioral change in food habits for the Bhutanese population is a potential possibility where initially every backyard is dedicated to for cultivation of this crop. Gradually, this backyard farming can be shifted to semi-commercial farming and then to commercial farming after all the required technologies are tapped and tested in our local environment. As we promote, popularize and publicize this crop, it will have a significant contribution to the nation's food security and help fulfill the aspirations of the country's food self-sufficiency goals.

Challenges and Prospects of Taro in Bhutan

Challenges

There is a lack of knowledge and documentation on the early history of crops and traditional knowledge associated with traditional agriculture practices in Bhutan. This crop has not received any attention either from food security perspective or on medicinal value significance. Therefore, incorporating Taro into the food security basket will entail proper research works encompassed into the regular works as is being done for other cereals and fruit crops. Some of the challenges concerning Taro production in Bhutan include;

- ✓ Shortage of farm labor in the rural areas is mainly due to out-migration to urban areas, coupled with production challenges. Labour shortage is the topmost constraint spelled by 53% of the total households in 2017 (MoAF, 2017).
- ✓ Wild Life predation on crops and livestock –Bhutan faces huge pressure from the wildlife on crops thereby resulting in substantial crop losses. Farmers have to sacrifice huge labor inputs for guarding crops. On average, a farmer spends about 67 days and nights guarding the crop (MoAF, 2017). Abandoning of agricultural land due to pressure from wildlife predation has increased the migration of rural communities to urban areas.
- ✓ No high yielding varieties of Taro as research has not entered into its exploration
- ✓ Limited knowledge and awareness of this crop's medicinal values and its uses
- ✓ Lack of adequate knowledge for production/consumption and research aspects in Bhutan.

Prospects

Consumer education on taro cultivation, nutritional values and health benefits could increase taro production. More research will enhance the understanding and contributions to crop and offer in the areas of food security, health and economic empowerment.

Recommendations

Given their potential of this crop to help in food security besides its significant therapeutic effect, scientific and systematic approach for research and development works the biological evaluation of plant products based on their use in the traditional systems of medicine forms the basis for an ideal approach in the development of new drugs from plants. The establishment of a research network of taro genetic resources across the SAARC countries and beyond would be extremely useful. The SAARC agriculture center can play a pivotal role in fund support and coordinate regional program in the region. Some of the recommendations are;

- ✓ Identifications of location-specific technologies to suit a very diverse agro-climatic mountain farming situation
- ✓ Initiation of collaboration and linkages with the CGIAR system. There are no collaborative activities with the international and regional centers of Excellence - very important for a small country like Bhutan to access information, knowledge, research materials (germplasm), and innovations.
- ✓ Generate and disseminate suitable technologies on Taro crops after thorough research to support crop production of priority commodities for food self-sufficiency and rural income generation.
- ✓ Identify and recommend the best crop varieties and management practices for enhancing the production and commercialization of the different commodities.
- ✓ Marketing and Value Chain studies-The market values chain studies help in optimizing the entire commodity production chain from primary production systems, through post-harvesting, storage, and preservation, transport and marketing to value addition.

Conclusion

Considering the multiple usage and importance of Taro both for health and food security in Bhutan in particular and in the SARRC region in general, there is a need for special attention in terms of research and development works to enhance the livelihood and wellbeing of the lives of rural people, particularly in remote parts of developing countries with few health facilities. Taro having tremendous medicinal value can be explored further to be utilized for the treatment of some common diseases besides helping the people to secure food. As the plant has been studied for various pharmacological purposes such as analgesic, anti-inflammatory, anti-cancer, anti-diarrheal, astringent, nervine tonic, and hypolipidemic activity, it is necessary to exploit it to its maximum potential in the medicinal and pharmaceutical field.

Bhutan being primarily an agrarian country with 62.2% of the population dependent on agriculture for their livelihood, venturing further into this crop will help meet the food self-sufficiency and poverty alleviation goals. Given the nature of farming practices done for this crop at subsistence level in small farm size (backyard), focusing on its promotion organically under multiple cropping systems can be effective and efficient using the improved technologies generated by the fellow SAARC region scientists. It is felt important to initiate a cross-country study on genetic diversity of taro, crop suitability, and different methods of cultivation for crop improvement and conservation and value addition. There is a need for greater regional cooperation in the promotion of climate-resilient and productivity-enhancing technologies among countries in the region. The key focus area of agricultural science, technology, and innovation development and adoption will require immense policy and bureaucratic support from all levels of governance of the member countries to eliminate poverty and hunger by calling for actions of all stakeholders while protecting the environment. Cross-border technology transfer is critical for countries in the SAARC region to achieve SDGs.

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Chapter 5

Prospects of Underutilised Taro (*Colocasia esculenta*) for Sustainable Biodiversity and Nutritional Security in India

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Abstract

Taro [*Colocasia esculenta* (L.) Schott] is an important tropical tuber crop widely cultivated in the different states of India. Extensive research has been conducted on biodiversity and utilization of taro. Taro germplasm exhibits wide genetic diversity offering great scope for improvement including biofortification. Eighteen high yielding (12-38 t/ha), high starch (12-24.5%), leaf blight tolerant varieties have been released for cultivation in India. There is many high-yielding, leaf blight tolerant landraces exist in India. Taro is consumed mostly as a vegetable and used in an array of delicious Indian cuisines across India. In North-eastern India, taro forms an important secondary staple food. The proximate composition of taro leaf and corm has been analyzed and nutritional values are well documented. The pharmacological properties of taro are well established while its clinical worthiness is yet to be ascertained. Taro starch has ambient functional properties and great scope for wide utility in industries. Starchy staples such as taro can substitute the affordable least-cost nutrient adequate diet for nutrient adequacy in India. Taro has a well-established marketing network system in India while a significant proportion is also exported to countries such as UK, UAE, USA and Gulf countries. SWOT analysis indicates that taro has great scope in India.

Introduction

Taro [*Colocasia esculenta* (L.) Schott] is herbaceous, perennial tuber crop species belonging to the monocotyledonous family Araceae. It is believed to be one of the earliest cultivated tuber crops in the world. The origin, dispersal history and cytogenetics of taro have been reviewed by Chair et al. (2016). Taro has two distinct groups: the *eddoe* (*C. esculenta* var. *antiquorum*) has a relatively small corm surrounded by large well-developed cormels and the *dasheen* (*C. esculenta* var. *esculenta*) has a large central corm surrounded by several small cormels arising from its surface (Kay and Gooding, 1987). It is the fourteenth most consumed vegetable worldwide (Lebot and Aradhya, 1991). Taro plants grow to a height ranging from 0.50 to 2.00 m with underground starchy corm which produces at its apex a whorl of large leaves with long petioles and bears lateral cormels. The leaves are elephant ear-shaped, 20-50 cm long, with rounded basal lobes. Taro corms contain carbohydrates, proteins, essential minerals like potassium, calcium, phosphorous, vitamins and dietary fibres (Onwueme, 1978; Lambert, 1982; Hanson and Imamuddin, 1983; Bradbury and Holloway, 1988; Opara, 2001; Kobayashi et al., 2011; Mergedus et al., 2015). Taro corms, cormels, leaves, stalks and inflorescence are utilized for human consumption. Taro leaf is rich in carotene, potassium, calcium, phosphorous, iron, riboflavin, thiamine, niacin, vitamin A, vitamin C and dietary fiber (Bradburry and Holloway, 1988; Opara, 2001). Nutritionally, taro corm and cormels contain more than twice the carbohydrate content of potatoes and yield 135 kcals per 100 g. Proximate composition of the taro corm, on a wet matter basis include; 63-85% moisture, 13-26.8% carbohydrate (mostly starch), 0.34-1.4% protein, fat 0.11-0.36%, 0.60-2.5% crude fibre, 0.6-2.5% ash, vitamin C (7-14.3 mg/100 g), thiamine (0.03-0.18 mg/100 g), riboflavin (0.04 mg/100 g), and niacin (0.78-1.3 mg/100g) (Tmesgen and Retta, 2015). Dry taro corm contains 13.06-25.7% protein, 1.06-1.84% ash, 1.04-3.6% fat, 1.02-2.12% fibre and 62.43-76.08% carbohydrate (Boampong et al., 2019). Very low content (per 100 g dry matter) of protein (2.5%), fat (0.78-1.2%), crude fiber (2.67-3.3%), starch (14.5%), sugar (1.3-1.5%), and dry matter (15.2-16.4%) and minerals, such as, Na (26 mg), Mg (1.42 mg), K (26.9 mg), and Ca (2.28 mg) has been reported (Lenka et al., 2013). Taro corms/cormels and leaves may contain oxalic acid and generally may be acrid. Total oxalate contents in fresh corm/cormel vary between 33 and 156 mg/100 g and soluble oxalate content between 19 and 87 mg/100 g. Insoluble oxalate contents vary between 29.35 and 73.97% of the total oxalate contents in tested taro corms (Huang and Tanudjaja 1992). Taro leaves contain 414 mg total oxalate (236 mg soluble and 178 mg insoluble) per 100 g fresh leaf (Savage and Dubois, 2006). Taro corm starch consists of 17-28% amylase, and the remainder as amylopectin (Oke, 1990). Taro corm may contain significant levels of mucilage between 6.84 and 10.0 g per 100 g (Nip, 1980; Tavares et al., 2011), depending on the extraction method. Mucilage from taro has emulsification and/or stabilization properties (Lin and Huang, 1993; Tavares et al., 2011). Nutritional qualities of taro are summarized by Matthews (2010) and Laxminarayan (2020). Taro corms, cormels and leaves are used as vegetable and consumed after roasting, toasting or boiling or, used in various dietary preparations. Taro corm's flour can be used in bread, cookies, baby food, pasta, or other products and for diabetics and weaning food for infants and those with gastrointestinal disorders or processed into fresh or fermented pasta, flour, drink, and crispy chips (Temesgen and Retta, 2015; Mulyaningsih et al., 2019). Taro is also useful in curing ailments such as tuberculosis, ulcers, pancreatic disease, inflammatory bowel and gall bladder disease and fungal infection (Emmanuel-Ikpeme et al., 2007; Singh et al., 2012).

Taro is widely cultivated, mostly as a staple or subsistence crop, throughout the humid tropics to subtropics, and in many warmer regions of the temperate zone. In most countries, taro is either a backyard or home garden crop or is cultivated by small-holders. It has been grown in tropical Asia for more than 10,000 years (Fullagar et al., 2006) and is now cultivated throughout the wet tropics (Matthews et al., 2017).

In India, taro is known by several local names like *Arbi*, *Chaembu*, *Shaeppamkizhangu*, and *Ghuiyaa* at different geographical locations. Taro is an important vegetable crop cultivated throughout India with greater diversity in North-Eastern, Eastern and Southern India (Srinivas et al., 2011); North-East India is being considered as one of the centers of origin for taro (Lakhanpaul et al., 2003). It is widely used as a tuber vegetable in India, whereas it is the staple food and also very closely associated with culture in many of the South Pacific islands. Taro fetches a higher price than cassava or sweet potato. Despite the economic importance of taro, its cultivation in India is generally subsistent with semi-commercial crops.

Apart from *eddoe* and *dasheen* types, there is another type of taro (*C. esculenta* var. *stoloniferum*) known as *swamp taro*, cultivated in marshy/shallow to waterlogged conditions in Assam, Bihar, Eastern Uttar Pradesh, West Bengal and North-Eastern states for its edible stolons or runners (Sivakumar et al., 2005; Roy Chowdhury et al., 2006). Swamp taro, a potential vegetable crop that originated from Assam or the North-Eastern part of India has natural adaptability to such conditions. In North-Eastern India, swamp taro is locally known as '*pani kachu*' or '*lati*' or '*kachu lati*' grows naturally under swampy conditions and hence referred to as swamp taro. Depending on varieties, leaves, petioles, stolons or runners are consumed as green vegetables especially in Assam, Bihar, Eastern Uttar Pradesh and West Bengal (Sivakumar et al., 2005; Goswami and Sen, 2000; Saud and Barua, 2000). There is potential for the cultivation of this crop in about 1.2 million ha in waterlogged/marshy land in these states.

This paper reviews the R & D on taro in India covering genetic diversity, nutritional values and utilization as a vegetable and its pharmacological uses and suggests recommendations for further R & D activities that could be useful in development of varieties upscaling taro utilization for food, nutritional and livelihood security among SAARC countries.

Taro for Biodiversity and sustainability

Cytology and ploidy variation

Chromosome studies conducted in taro have been reviewed (Pillai et al., 1999; Sreekumari, 1997). Cultivated varieties of taro belong to two main ploidy levels (Sreekumari and Mathew, 1991 a, b; Sreekumari, 1992), diploid (2n= 28) and triploid (2n=42). Detailed karyotype, genome size and RAPD marker analysis to assess genetic diversity in *eddoe* types (Das et al., 2015) revealed genotype-specific chromosomal characteristics and structural alterations in chromosome with variations of ploidy from 2n = 2x = 28 in cultivars such as Mothan, Muktakeshi, Sree Kiran, Sree Pallavi and Sonajuli to 3n = 3x = 42 in cultivars such as Banky, DP-25, Duradin, H-3, and Telia. Highly significant variations in the genomic length (46.96μm in cv. Sree Kiran to 100.49μm in cv. Duradin), volume (18.22μm^3 in cv. Sonajuli to 38.22μm^3 in cv. Duradin) and total form percentage (24.94% in cv. Sree Kiran to 39.04% in cv. H-3) confirm near-metacentric to metacentric chromosomes in the karyotype. Significant variations in the 4C DNA content (7.24 pg in cv. Sree Kiran to 18.24 pg in cv. Duradin), and genome size (~7095 to 17875 Mbp) were recorded. The high genome size in all the triploid varieties (3x = 42) could be due to the presence of an extra set of chromosomes in the genome or a high amount of repetitive DNA. The variation in the genome size at the variety level was presumably attributed to the loss or the addition of highly repetitive sequences in the genome.

Genetic diversity

Taro is believed to have originated in South East Asia including India (Watt, 1889). From there, it probably spread to Egypt, Arabia and the Pacific. The hypothesis that North East India is the center of origin of taro was confirmed by many Indian workers. Wild forms still occur in various parts of South-Eastern Asia (Purseglove, 1972). Hence, the probability of finding a high genetic diversity is more in India. Supporting evidence was shown in the most recent study on genetic diversification and dispersal of taro using 11 microsatellite markers which revealed that the highest genetic diversity and number of private alleles were observed in Asian accessions, mainly from India (Chair, et al., 2016), thus proving that India is the main Centre of origin for taro from where, it dispersed to West Africa, Madagascar, Costa Rica, etc. As the North-Eastern states of India are regarded as the primary centers of origin of taro, a considerable level of diversity is expected among these accessions. Vinutha et al., (2015) morphologically characterized 25 taro accessions collected from different North-Eastern states of India using 27 above-ground characters based on a combination of NBPGR/IPGRI descriptors. PCA analysis revealed three principal components revealing 67.7% of the variability. The dendrogram generated using the R statistical package grouped the accessions into two broad clusters, which were further divided into 2 and 5 sub-clusters, respectively. It was also observed that geographically similar accessions were grouped under different clusters (Vinutha et al., 2015).

Another study (Mukherjee et al., 2016b) on genotypic and phenotypic coefficients of variation, heritability, genetic advance at 5% selection intensity and percentage of population mean of nine characters viz., plant height, leaf number, length and width of leaf lamina, number and weight of cormels per plant, weight of corm per plant, dry matter percentage in the cormel and cormel yield per plant from 14 cultivars of taro revealed highest genotypic coefficient of variation for dry matter percentage (47.91), which was 95.78% of the phenotypic coefficient of variation, whereas cormel yield per plant showed the widest range (819.37). Number of cormels per plant and dry matter percentage exhibited considerably higher heritability (84.90% and 91.70%, respectively) and genetic advance (81.19 and 79.00, respectively), indicating the potentiality of selection for improvement of such characters. These two characters were found to be positively correlated to cormel yield per plant. Path analysis revealed that weight of cormels per plant had highest direct effect on yield, indicating the importance of selection based on this character to increase cormel yield per plant. Multivariate analysis in taro was done to identify important characters which can be used for selecting the best parents in breeding programs (Pandey and Dobhal, 1997). Genetic variability, genetic diversity, heritability, genetic advance, correlation and path coefficient of various quantitative traits and their contribution towards yield have been reviewed by (Kathayat et al., 2018). Bhanu Prakash et al., (2019) studied the extent of genetic diversity on 19 quantitative characters including leaf, petiole, corm, cormel and corm biochemical characters. The study revealed that the characters such as leaf area, corm weight/plant, cormel weight/plant and yield/plant contributed maximum towards diversity. On the other hand, Kumar et al., (2019) reviewed the genetic variability, genetic diversity, heritability, genetic advance, correlation and path coefficient of various qualitative and quantitative traits of taro belonging to the NEH region to formulate a sound breeding plan for its improvement. Multivariate analysis of divergence among 40 taro accessions collected from the NEH regions for 17 characters showed no relationship between genetic divergence and geographic distribution of accessions suggesting geographic diversity is not adequate as an index of genetic diversity (Supriya Devi et al., 2019).

Genetic diversity in taro at the molecular level (Asha Devi, 2012) and morphological using RAPD (Lakhanpaul et al., (2003) have been revealed in detail. Three out of 13 primers showed 100% polymorphism for 32 taro accessions belonging to 28 morphotypes. Percent polymorphism varied from 60 to 100 among the polymorphic primers with similarity coefficients ranging from 0.50 to 0.98. No two accessions showed a similarity coefficient value of one thereby indicating their distinctness and presence of high genetic diversity in Indian taro germplasm. Dendrogram obtained from UPGMA analysis grouped 32 accessions in four clusters and three accessions were placed as outliers. Clustering patterns did not show any strict relationship with geographical distribution, morphotype classification and genotypic diversity. Furthermore, accessions classified, as belonging to the same morphotypes group did not always cluster together. Presence of a very close gene pool of the wild, weedy and cultivated forms with extreme levels of phenotypic and genotypic variation was attributed to the high genetic diversity. A similar study was carried out by Pillai and Lekha (2008), where RAPD was used in morphologically different 45 taro accessions from CTCRI. The variability was observed to range between 60-100%. Here, accessions from similar geographical locations tended to pool together. Morphological marker with a definite objective to find genetic variability amongst 20 taro genotypes from different agro-climatic zones in India concerning plant physical parameters viz., length of main sucker, no. of petioles, length of leaf lamina, weight of side tuber, number of side tuber, estimated corm yield, breadth of leaf lamina (Mandal et al., 2013) revealed that the genetic diversity corresponded with molecular data analysis. Bhatacharjee et al., (2014) studied the genetic divergence among twenty genotypes of upland taro using D2 and Principal Component Analysis for identifying diverse parents for use in improvement programs. Association of various morphological characters and their direct and indirect relationship between yield and its contributing traits in taro (Yadav et al., 2018) revealed that the yield per plant has significantly positive correlation at phenotypic level with weight of cormels per plant (0.695), number of cormels per plant (0.595), weight of corms per plant (0.451) and day to sprouting (0.293) but negatively correlated with plant height (-0.364), petiole length (-0.303), leaf width (- 0.287) and leaf length (-0.296).

Amplification of genomic DNA in 10 genotypes using Operon primers yielded 230 amplified DNA fragments ranging from 200 to 2500bp, of which 79 bands were polymorphic (Das et al., (2015). A total of 8 unique RAPD bands were observed among the 10 taro genotypes studied revealing primer-wise polymorphism from 16.66 to 47.36% with an average polymorphic percentage of 34.34%. However, among the cultivars, the polymorphic percentage varied from 3.7% (between cv. DR-25 and cv. Duradin and cv. Telia and cv. H-3) to 41.94% (between cv. Mothan and cv. Muktakeshi). Genetic similarity based on Jaccard's coefficient varied from 0.54 to 0.96, indicating wide genetic variability among the varieties based on RAPD markers. Similarity measures and cluster analysis generally reflected the expected trends in relationships of diploid and triploid taro varieties. Many markers *viz*., RAPD and ISSR have also been used to check the fidelity of *in vitro* regenerated taro plants (Hussain and Tyagi, 2006). Nusaifa Beevi et al., (2011) used RAPDs to reveal genetic diversity of 60 lines of South Indian taro). The RAPD primers were able to differentiate between wild and cultivated forms as well as distinguish between diploids and triploids. Diversity of 21 taro accessions from different parts of the Andaman Islands in addition to three commercial varieties as reference genotypes was assessed by Singh et al., (2011) using both RAPD and ISSR. Both the marker systems divided the population into two sub-clusters, one having the reference genotypes and the other having the island population and showing correlation with morphological parameters.

Another study on genetic characterization of locally cultivated taro germplasm from 11 Districts of Nagaland was done by Mezhii et al., (2017) using microsatellite markers. Twenty-eight microsatellite markers were used to analyze 50 accessions of taro. The average number of alleles per locus was 1.89. Both altered alleles and null alleles were observed. The number of alleles ranged from one to four. The overall size of amplified products ranged from 117bp to 685bp. The PIC values ranged from 0.41 - 0.93 indicating high specificity and discriminatory power of the markers. Analysis of molecular variance (AMOVA) revealed that most variation among individuals within population was 100%. It appears that high within-population variation is a characteristic of *Colocasia*. The present study showed that the germplasm of Nagaland was diverse but somewhat uniformly distributed across the state.

The gene bank at the ICAR-CTCRI comprises 429 taro germplasm collected from all over India with trait-specific new collections being added every year. In 2020, a collection was obtained from the Northeastern regions, especially from Assam exhibiting a wide variability in tuber shape (Fig. 1) as well as leaf and petiole characters (Fig. 2). The study by Vinutha (2014) based on the frequency of the phenotypic characters across the 25 accessions from NEH region had 0.63 Shannon Weaver's diversity index (H). This represents a higher value of diversity index when compared to a similar study conducted in Ethiopia (H = 0.27) using 100 accessions (Beyene, 2013). This higher diversity index proves the center of origin is to be the center of diversity too.

Fig. 1: Tuber variability observed in *eddoe* taro collections

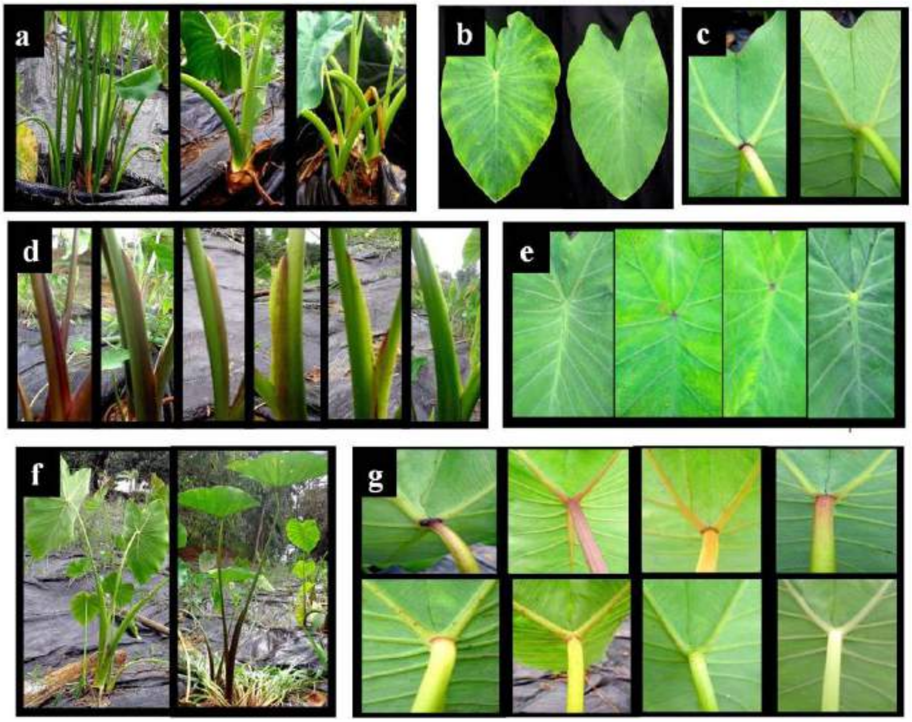

Fig. 2 (a-g): Comparison of variations in morphological traits. a - Tillering. b - Leaf variegation. c - Sinus color. d - Sheath color. e - Petiole junction color and pattern (Upper). f - Lamina orientation. g - Petiole junction pattern and color (Lower)

The cormels are planted in April-May and harvested after six months. Important characters were recorded based on modified IPGRI descriptors and catalogs and bulletins were published (Unnikrishnan et al., 1987). A wide spectrum of genetic variability was noticed among them for several characters, especially growth habit, pigmentation on different plant parts, crop duration, flowering habit, fertility, open-pollinated fruit and seed set, size, shape and yield of corm and cormels, cooking quality, tolerance to leaf blight disease etc.

Flowering and seed setting

Flowering and seed set are the pre-requisites for conventional hybridization. Many clones flower and produce viable seeds (Abraham and Ramachandran, 1960; Jos and Vijaya Bai, 1977). The inflorescence of taro is a spadix which is cylindrical with basal female flowers followed above by neuters compressed by the neck of the spathe and has a protruding male region terminating with a sterile appendage and completely enclosed by a spathe. Inflorescence emits a pleasant smell. The inflorescence is visited by small flies attracted by the smell during this period only facilitating cross-pollination. The prevalence of cross-pollination in many aroids is well known. The stigma receptivity was noticed up to 68 hrs.

Application of ascorbic acid (500 ppm) or gibberellic acid (GA_3 1000 ppm) to the shoot apex at 15 days intervals from 2.5th-month planting till 6th month is effective in inducing flowering response in taro as well as seed setting percentage (Indira add Mukherjee, 1991). During the pre-flowering phase, distribution of starch was more in the central core of the apical meristem in the flowered varieties compared to the non-flowered. Similarly, presence of lipids was more conspicuous in the apical meristematic region of the flowering plants. Presence of statolith was a unique feature observed only in GA_3, treated plants, with an increased intensity of starch grains in the central core of the meristematic shoot apex. Abundant formation of suckers was associated with GA_3 treated plants whereas in ascorbic acid-treated plants, this was absent. Ascorbic acid was hastening the flower initiation. Application of ascorbic acid (500 ppm) had not only induced flowering and seed setting but also hastened the flower initiation by 10 to 30 days in taro.

The flowering of taro varies among cultivars and prevailing climatic conditions. Flowering is seasonal between August and October (3-4 months after planting) (Sreekumari and Pillai, 1994; Pillai et al., 1999). Flowering is rather very low in cultivated forms and is associated with plant types having abundant suckers. However, frequency of flowering in wild taro grown in marshy areas or waterlogged conditions is notably high everywhere. The genetic resources maintained at the ICAR-Central Tuber Crops Research Institute (CTCRI) showed that natural flowering is neither profuse nor predictable which might be correlated to the characteristics of the location, which is as follows: latitude-8^{o} 40^{o} N; longitude- 77.0^{o}C E; minimum night temperature -19^{o}C; maximum day temperature 33.4^{o}C; rainfall - 1400-1500mm; daylength-11 hr 23 min (shortest in Dec.) to 12 hr 39 min (longest in June) for crop season-April to October. In addition to the environmental factors, flowering is also influenced by the ploidy status of the genotype. Though both diploid and triploid accessions flowered, frequency of flowering was more among diploids compared to triploids ranging from 2.5 to 5.0% in the former and from 0.8 to 2.5% in the latter (Sreekumari et al. 2004). Floral biology was studied and pollination techniques standardized by many workers. Diploid taro varieties exhibit protogyny and stigma remains receptive 24 h before anthesis and 24 h after pollen shed. On the day of opening of the inflorescence, the successful pollination was 50-86%. Limited receptivity was noticed up to 36 hours after the liberation of pollen and there is no seed set beyond that period (Jos and Vijaya Bai, 1977; Sreekumari and Pillai, 1994). The pollen grains are found coned out through pores. Pollen sterility varied between 1 and 28% in diploids and from 70 and 100% in triploids (Sreekumari and Pillai, 1994). Cryostorage of pollen grains significantly sustains their viability, can eliminate the conventional breeding barriers such as the asynchronous and protogynous nature of flowering and other cytogenetical anomalies and can be successfully used in hybridization for improving the traits of interest (Mukherjee et al., 2016a). The stainability/viability of pollen ranged from 90% after 24 hr. to 80% after 72 hr. anther dehiscence. In fresh pollen, it ranged from 85 to 92% depending on the variety. Germ-tube emergence ranged from 13.7 % after 24 hr to 16 % after 72 hr of preservation. In fresh pollen, it ranged from 14.7 to 19.5% depending on the variety selected. The viability assessment of 2 months stored pollen of different genotypes revealed a stainability percent in the range of 78.8-80% and the germ-tube emergence ranged from 12.7 to 15.5%. The *in vitro* germination of cryostored pollen hybridized seeds were on par with seeds obtained from conventional breeding mediated with fresh pollen.

Pollen sterility is a common phenomenon in triploid taro and this was attributed to abnormal tapetal development and meiotic irregularities in microsporogenesis (Bail et al., 1971). Although triploid taro exhibits pollen sterility, they do not result in seed setting (Sreekumari and Pillai 1994). Fruits can be produced by artificial dusting of pollen from the same flower on the stigma (Geethakrishnan and Pillai, 1996). Fruits develop and ripen about 30-40 days after pollination. Each fruiting head is a cluster of densely packed berries. Each berry generally contains 1 to 40 seeds. Seeds have no dormancy, can germinate within 7 days but retain viability up to 3 months when stored at room temperature or for a longer period when stored in a desiccator (Pillai and Unnikrishnan, 1992).

Genetic improvement

The improvement program of taro has been largely dependent on the exploitation of the existing genetic variability among the cultivars (Kuruvilla and Singh, 1981; Velayudhan and Muraleedharan, 1985; Singh and Singh, 1985; Unnikrishnan et al., 1987; 1988). Many taro varieties were released by ICAR-CTCRI through a selection of elite lines from the germplasm collection, evaluation trials such as row trials, preliminary evaluation trials, advanced yield trials and finally on-farm trials through hybridization and evaluation of the progeny before the release of superior selections. Of the two existing ploidy levels (diploids and triploids) in taro, triploids are superior over diploids for use as parents in hybridization many important traits like plant height, shoot girth, leaf length and breadth, corm and cormel weight as well as cormel number (Sreekumari et al., 2004). In the case of corm and cormel yield highly significant increase was observed in the triploids except in the case of cormel number which was significantly more in diploid plants. This implies that for breeding high-yielding varieties in taro it is desirable to take triploids rather than diploids as parents.

One of the major breeding objectives in taro is development of taro leaf blight (TLB) tolerant high yielding varieties having no acridity and good cooking quality. During the past few years systematic screening has been conducted at ICAR-CTCRI for identification of source of resistance to TLB and few tolerant/resistant lines identified. Further efforts are in progress to incorporate this resistance into existing high-yielding lines which are otherwise susceptible to taro leaf blight disease.

Another major hurdle in taro improvement program is the synchronization in flowering of the parents. To an extent this problem in flowering was overcome by storing the pollen under refrigeration for a short duration (about 20-30 days) and in cryopreservation for a longer period and then using this pollen for hybridization. The second problem faced is the establishment of the germinated seedlings under *in-vivo* conditions. Here again, *in-vitro* methods may be adopted for raising the seedlings. Earlier, the first hybrid taro Sree Kiran was released by ICAR-CTCRI, in India, which is high yielder with good storability of cormels (about 60 days). However, this variety is moderately susceptible to leaf blight. Hence, the breeding program envisaged now is development of taro varieties with tolerance/resistance to leaf blight. Further, to speed up the breeding program, work on identification of molecular markers associated with TLB resistance is in progress which can be used for marker-assisted selection.

Polyploidy breeding

The natural triploids in taro were found to be significantly superior in yield compared to diploids (Sreekumari *et. al*., 2004). To evolve artificial triploids in large numbers, attempts on induced tetraploids for intrepid crossing for the production of artificial triploids are undertaken at the ICAR-CTCRI. Colchicine (0.2%) applied on the emerging shoot tip for 6-8 hours has been observed successfully in inducing tetraploids up to 31% in the different accessions of taro tested. But establishment problem has been encountered in the field (Sreekumari et al., 2004). Evaluation of the tetraploids revealed that some of them were better in performance compared to the control (Sreekumari and Mathew, 1991a, b). However, no polyploid variety could be developed.

Varieties released

Taro has a wide variability and a large number of local cultivars are grown in different parts of India. The ICAR-Central Tuber Crops Research Institute and other State and Central Agricultural Universities under All India Coordinated Research Project on Tuber Crops have released several high-yielding varieties of *eddoe* taro which are suitable for different agro-ecological zones (Table 3). Narendra Arvi-1, Narendra Arvi-2, Bidhan Chaitanya, Muktakeshi, Indira Arvi-1, Pani Saru-I, Pani Saru-II, Rajendra Arvi-1, Bhu Kripa and Bhu Sree, are suitable for eastern zone; Satamukhi and Saharshamukhi for western zone; and Satamukhi, Sree Rashmi, Sree Pallavi, Sree Kiran and Co-1, Bhavapuri and Godavari Chema for southern zone. Apart from the released varieties, some of the local cultivars such as Thamarakkannan, Telia, Paramahamsa, Nadia, Gadamoni, Kadma, White Gauriya, Kakakachu, Pachmukhi, Ahina Kachu are very popular in different states of India. In Manipur, Hao-paan, Ingkhol-paan, Mukhi-paan angangba, Mukhi-paan angouba, Paan-gong, Paan-angangba, Singda-paan and Yerum-paan are popular local land races (Devi et al., 2016). In *dasheen* type, Narendra Bunda-1 and Narendra Bunda-2 were released for Uttar Pradesh and Arunachal Pradesh. In Manipur the local cultivar Lam-paan is very popular (Devi et al., 2016). In general, the corm yield of *dasheen* is higher than cormel yield of *eddoe*. The average yield of *dasheen* taro is 38 t/ha with shelf-life of 4-5 months (Sunitha et al., 2016). In dasheen taro, NM/2017-1 (Nayagarh), NM/2017-2 (Chakkapada), NM/2017-3 (Jalandhar), VHAK/2017-4 (Joida) and Garu are available local landraces. In swamp taro type, BCST 23, BCST 21, BCST 2, BCST 4 and BCST 15 are the promising cultivars suitable for marshy conditions of West Bengal, Assam and Odisha. In Tripura, two types of swamp taro (Tuini, Khema) are cultivated. These are green petiole swamp taro (petiole green and corm skin brown with slight greenish tinge) and red petiole swamp taro (petiole dark reddish/maroon and corm skin dark brown and maroon) (Das et al., 2016).

Of the eight taro varieties released by ICAR-CTCRI (Table 3), Sree Kiran is the first hybrid taro released in India in the year 2004 by hybridization of fertile diploid parents from the germplasm, having high yield and good keeping quality. Flowering inadequacies, occurrence of sterile triploid genetic stocks and protogynous nature of the spadix are the main obstacles for the genetic improvement of taro through hybridization and selection. Sree Rashmi, a selection from the germplasm (C-149), is an acridity-free variety with edible leaves, corms and cormels. It also gives economical yield under low input levels. Sree Pallavi, another selection from germplasm (C-266), collected from Meghalaya, is a tall variety with large number of small-sized tubers and is field tolerant to leaf blight and Dasheen mosaic virus. Muktakeshi, a taro variety released from the Regional Centre, ICAR-CTCRI has tolerance to leaf blight. The swamp taro varieties Panisaru 1 and Panisaru 2 have been released in 2005 by the Regional Station, Bhubaneswar for cultivation in Odisha having field tolerance to leaf blight and the ability to grow in submerged or waterlogged conditions. Two varieties of taro were released recently in the year 2017; Bhu Kripa a selection from the local landrace, Jhankri and the second variety Bhu Sree, another selection from a landrace, Sonajuli. Further research is in progress to develop high-yielding taro varieties with no acridity, good cooking quality and tolerance to TLB disease.

Table. 3. Improved varieties of taro released by the ICAR-Central Tuber Crops Research Institute and other State and Central Agricultural Universities under All India Coordinated Research Project on Tuber Crops.

Name of variety	Released by	Tolerance to TLB / DMV*	Duration (months)	Average yield (t/ha)	Starch content (%)	State recommended for cultivation
Sree Pallavi	ICAR-CTCRI	Yes	7	16	24.5	Kerala
Sree Rashmi	ICAR-CTCRI	Moderately tolerant to TLB; Tolerant to DMV	7	18	15.5	Kerala
Sree Kiran	ICAR-CTCRI	Moderately tolerant to TLB	7	29	18	Kerala
Muktakeshi	ICAR-CTCRI	Resistant to TLB	6	20	18	Odisha, Chattisgarh, Jharkhand
Pani Saru-I	AICRP (TC)	Suitable for waterlogging	7	16	12	Odisha
Pani Saru-II	AICRP (TC)	Suitable for waterlogging	7	13	17	Odisha
Bhu Kripa (Jhankri)	ICAR-CTCRI	Tolerant to TLB	7	12	14	Odisha
Bhu Sree (Sonajuli)	ICAR-CTCRI	Tolerant to TLB	7	12	17	Odisha
Satamukhi	AICRP (TC)	Moderately tolerant to TLB	6	15	20	AndraPradesh, Bihar, WB, TN, Kerala

Name of variety	Released by	Tolerance to TLB / DMV*	Duration (months)	Average yield (t/ha)	Starch content (%)	State recommended for cultivation
CO-1	AICRP (TC)	Moderately tolerant to TLB	6	24	22.5	Tamil Nadu
Narendra Arvi-1	AICRP (TC)	Moderately tolerant to TLB	6	13	19.5	UP
Narendra Arvi-2	AICRP (TC)	Resistant to TLB	6.5	16	19	UP, Bihar
Bidhan Chaitanya (BCC-1)	AICRP (TC)	Resistant to TLB	5.5	15-20	22	WB
Indira Arvi-1	AICRP (TC)	Resistant to TLB; Tolerant to waterlogging	8	22	-	Chattisgarh, MP
Bhavapuri	AICRP (TC)	Moderately tolerant to TLB	6	30	15	Andhra Pradesh
Rajendra Arvi-1 (RA-1)	AICRP (TC)	Moderately tolerant to TLB	6	18	-	Chattisgarh, Jharkhand
Godavari Chema (KCS-3)	AICRP (TC)	Moderately tolerant to TLB	5.5	20	-	AP, Telengana
Narendra Bunda-1	AICRP (TC)	Moderately tolerant to TLB	5	38	68 (DMB)	UP, Arunachal Pradesh

*TLB-Taro leaf blight, DMV-dasheen mosaic virus

Taro for Nutrition Security

Nutritional value

Taro is primarily grown as a vegetable for its edible, starchy corms/stolons but its petiole and leaves are also used as vegetable for nutritional and medicinal purposes. Green leaves of taro are a rich source of β-carotene, ascorbic acid, folic acid, riboflavin, B-vitamins, vitamin A, β-sitosterol, and steroids and minerals such as iron, calcium, potassium, phosphorus, magnesium (Kirtikar and Basu 2005). Taro leaves have flavonoids (orientin, isoorientin, isovitexin, vicenin-2,orientin7-Oglucoside, isovitexin 3′-Oglucoside, vitexin X′′-Oglucoside, leteolin 7O-glucoside, and phytochemicals such as alkaloids, saponins, tannins, phytosterols, glycoside, pholbatanins, terpenoids and anthocyanins (cyanidin-3-glucoside, pelargonidin-3-glucoside and cyanidin-3-rhamnoside) (Kumavat et al., 2010; Dhanraj et al., 2013; Chakraborty et al., 2015; Dwivedi et al., 2016; Keerthy and Joshi 2019; Keshav et al., 2019). Therefore, anthocyanins may be responsible for antioxidant activities and the hepato-protective as well as anti-lipid peroxidative properties of taro leaves. Fresh taro leaves contain 62.15 to 83.61% moisture (Awasthi and Singh 2000; Longvah et al., 2017). The protein, ash, crude fat, crude fiber, carbohydrates, starch, total chlorophyll, total carotenoids and ascorbic acid content of dry taro leaves varied from 20.65 to 26.25%, 9.85 to 13.95%, 2.01 to 4.16%, 20.54 to 26.15%, 34.17 to 43.36%, 15.64 to 20.61%, 1.53 to 1.91 mg/g, 1.20 to 1.95 mg/l00g and 26.35 to 36.08 mg/l00g, respectively in taro collections (Gupta et al., 1989; Awasthi and Singh 2000). One hundred gram of dry taro leaves contain calcium (1.3 g), copper 0.8 mg), iron (10 mg), magnesium (300 mg), phosphorous (600 mg), potassium (1.7 g), sodium (0.04mg), manganese (4.37 mg) and zinc (1.75 mg) also (Gupta et al., 1989). One hundred grams of fresh taro leaves contain 3.42% protein, 2.3% ash, 1.38% crude fat, 3.69% carbohydrates, and 40.71 mg ascorbic acid, 216 mg Ca, 0.29 mg Cu, 3.41 mg Fe, 159 mg folic acid, 59.44 mg Mg, 57.88 mg P, 0.4 g K, 12.08 mg Na, 1.3 mg Mn and 0.82 mg Zn (Longvah et al., 2017). Fresh taro leaves are heart-friendly food as they contain 48-57% total polyunsaturated fatty acids (Longvah et al., 2017) which are higher than other green vegetables (Amaranth, Spinach, Mustard and Fenugreek). Taro leaves are also good source of phytochemicals such as phenolic compounds like gallic acid, chlorogenicacid, and catechins (Gupta et al., 2019). The major phytochemicals present in taro leaves and their pharmacological properties are summarized by Gupta et al., (2019). These phytochemicals are apigenin, caffeic acid, caffeoylglucaric acid, catechin, chlorogenic acid, chrysoeriol, p-coumaric acid, diosmetin, D-glucaric acid, glycosylflavone, vitexin, isovitexin, leucoanthocyanin, luteolin, orientin, ouabarin, scoparin, schaftoside, synaptic acid. They have many pharmacological properties such as skin cancer chemopreventive, antiproliferative of cancer cells, anti-inflammatory, anti-metastatic, inducing apoptosis in cancer cells, antioxidant, antineoplastic, anticancerous, neuroprotective, antimicrobial, estrogenic, antipyralgesic, cardioprotective, and antinematodal.

Taro corms are rich in starch and essential nutrient such as thiamine, riboflavin, niacin, oxalic acid. Taro corms/cormels as vegetable and value-added products such as taro corm chips are found in few of the Indian supermarkets. The corms can be baked, roasted or boiled and are usually eaten with other ingredients. Taro corms can be fried, dried and made into flour, grated, made into a stew or consumed in many other ways. It is often used in many traditional cultural dishes in Indian food system.

Taro corm contains antioxidant phytoconstituents such as tannins, saponins, flavonoids, steroids, carbohydrates, proteins, and glycosides which attribute for strong antioxidant potential and free radical scavenging capacity when assayed *in vitro* with 1,1-diphenyl-2-picrylhydrazyl (DPPH), nitric oxide (NO) and 2,2'-azino-bis (3-ethylbenzothiazoline-6-sulphonic acid) (ABTS) radical scavenging activities (Yadav et al., 2017).

Acridity of taro leaves, corms and cormels

Taro leaves contain the anti-nutritional factor as oxalate which attributes to its acridity. All parts of taro show itching on human skin when contacted, which is due to the presence of sharp oxalate crystals in the form of raphide in specialized cells known as idioblasts. The oxalate crystals are also attributed to kidney stone formation. This acridity can be eliminated by cooking with lemon which contains citric acid or tamarind which contains tartaric acid. The density of cells containing oxalate crystals is lowest in older leaves. The study conducted on 11 different Indian green leafy vegetables by Radek and Savage (2008) revealed, high total oxalate content in taro leaves (5.14 g/100 g dry matter), which was lower than spinach (12.58 g/100 g) and amaranth (10.06 g/100g) but more than curry leaves (2.77 g/100 g) and radish leaves (0.21 g/100 g). As the oxalate binds with calcium and forms calcium oxalate crystals, free calcium is not available for utilization by the body.

Taro leaves and corms/cormels contain oxalic acid in the form of soluble oxalates (Na^+, K^+ and NK_4^+ salt) and insoluble form, mainly as calcium oxalate. Taro plant parts exhibit acridity because of presence of calcium oxalate crystals present in the form of bundles of sharp needle-like structures known as raphides. Cells containing raphides are known as idioblasts. Corms/cormels of acrid taro cultivars contain more idioblasts than non-acrid cultivars. Furthermore, the raphides are arranged compactly in idioblast matrix in non-acrid corms/cormels whereas in acrid corms/cormels the raphides protrude out of the idioblast matrix. When idioblast cells containing raphides in acrid cultivars are disrupted by chewing/biting, the crystals are ejected forcefully and cause acidity. Taro plant parts when consumed cause irritation in the tongue and throat. They also irritate the skin when contacted. The proportion of soluble and calcium oxalate content in dry corms/cormels varied widely between acrid and non-acrid taro cultivars. The soluble oxalate content in dry corm/cormels of acrid cultivars varies between 0.04 and 0.09% whereas it varies between 0.12 and 0.18% in non-acrid varieties. The calcium oxalate content in dry taro corms/cormels of acrid cultivars varies between 0.62 and 0.84% whereas it varies between 0.07 and 0.15% in non-acrid cultivars. Thus, corms of acrid taro cultivars contain more calcium oxalate than soluble oxalates whereas the reverse was true for non-acrid varieties. This indicates that acrid taro cultivars synthesize more oxalic acid and store mainly as calcium oxalate whereas non-acrid cultivars have lower total oxalate content and a major fraction of the stored oxalate is present as soluble oxalates (Sundaresan 2005). Taro leaves of both acrid and non-acrid cultivars contain higher amount of total oxalates (6.5-7%) than the cormels (0.35-0.4% in non-acrid cultivars and (0.82 -0.90%) in acrid cultivars.

The intensity of acridity of taro plants is associated with the degree of protease activity in leaves, corms/cormels of taro. The protease activity in cormels of acrid taro cultivars varied between 20 and 35 units/100 mg protein/h whereas that of non-acrid cultivars varied between 2.5 and 8.5 units/100 mg protein/h (Sundaresan, 2005). The high intensity of acridity was presumably attributed to the high protease activity rupturing the cormel tissue and ejection of raphides into the ruptured tissue.

Cormels of some taro cultivars retain acridity even after normal processing. The intensity of acridity in fresh cormels can be reduced by traditional processing methods such as cutting of cormels into thin pieces, addition of organic acid in cooking medium, increase in cooking time, and change of water twice or thrice during boiling (Sundaresan, 2005). Cutting of taro cormels into 3 mm thick pieces significantly reduced acridity after boiling as compared to pieces of 10 mm thickness and peeled whole cormels. Cutting of taro cormels facilitates leaching out of calcium oxalate crystals into water and thereby reduces acridity. The calcium oxalate content in 3 mm, 10 mm thick cut pieces and peeled whole cormel of taro were 0.34, 0.48 and 0.55% respectively after boiling. In processing of 10 g size of taro cormels, addition of citric acid and tartaric acid (1%) significantly reduced calcium oxalate content to 0.23 and 0.27% respectively and associated acridity of taro cormels while citric acid imparted a bright color to the cooked samples. Addition of acetic acid and lactic acid could not reduce calcium oxalate content (0.43 and 0.48% respectively) and associated acridity in cooked cormels as compared to boiling without additives (0.70%). The effect of organic acid was attributed to the lowering of pH in the cooking medium and facilitating solubility of calcium oxalate. Soaking of taro cormels in organic acids for different lengths of times before boiling had comparable effect of instant boiling with organic acids on reduction of acridity. Soaking taro cormel slices in 1% citric acid for 6 hrs. followed by blanching for 5 min at 100^{o}C effectively removes acridity and improves brightness of chips (ICAR-CTCRI, 2019).

Oxalate and phytate content of taro flour samples prepared from different cooking conditions, varied from 25.8 to 119.5 mg/100g and from 20.1 to 80.6 mg/100g respectively. Oxalate and phytate content was significantly reduced in the flour samples prepared from slices cooked in water and lemon solution presumably due to leaching of soluble oxalate and phytate in the cooking medium. However, oxalate and phytate content were not significantly reduced in taro flour samples prepared from slices cooked in steaming as leaching did not take place in steam cooking as the sample was not in direct contact with the medium. The oxalate and phytate content were highly reduced 75.7% and 71.5% respectively in the flour samples prepared from slices cooked in lemon solution and minimally reduced (10.7% and 12.5% respectively) in the flours cooked in steam during 5 to 15 min cooking (Kumar et al., 2018).

Taro as vegetable: Recipes made from taro leaves

Taro has an important place in Indian cuisines. An array of recipes made from taro plants in India have been well documented (Sivakumar et al., 2013, 2019; Sunitha et al., 2016; Gupta et al., 2019). *Khatti bhujji* and *Patrodu* are the traditional recipes of Himachal Pradesh state (Kapoor, et al., 2010). *Khatti bhujji* (also *Garyali bhuiji*), is prepared from the whole taro plant usually during the *Diwali* festival. *Patrodu* is prepared from shallow fried or deep-fried taro leaves usually during rainy and winter seasons. *Patra* is a Gujarati dish prepared by coating taro leaves with a paste containing gram flour, water, and spices. *Turiya Patra* is a combination of ridge gourd and Patra. It is a Gujarati dish and often served during marriages. *Lavingya Patra,* another variation of *Patra,* is also a Guajarati dish and involves cooking thin layers of gram flour paste rolled up in tender taro leaves. *Alvati* is a *Konkani* cuisine. It involves well cooking of tender taro leaves with coconut masala and star fruit, jackfruit seeds or bamboo shoots, etc. to destroy oxalate crystal so as to avoid itchiness in the mouth. *Aluchi Bhaji* is a curry made in Maharashtra using taro leaves, peanuts, and Bengal gram (Gupta et al., 2019).

Taro plays a vital role in the food and nutrition security of people of North-Eastern India for centuries. Taro forms an important ingredient in traditional cuisines of the tribal populations in this region which constitute 12% of total tribal population of India (Sethuraman et al., 2013; 2019). Tribals prepare and consume an array of dishes from all parts of taro plant in both fresh and processed forms. During cropping season, taro tender leaves and petioles are prepared and consumed while semi-processed products of taro corms/cormels are eaten during lean season as a substitute for cereals and vegetables. Semi-processed taro products such as fermented and dried taro leaves, dried taro leaves, dried taro leaf cakes, dried taro petioles and dried taro corms together replaced 94% of cereal and vegetable consumption whereas semi-processed taro products such as fermented and dried taro leaves and dried taro petioles together replaced 45% of vegetables during lean season. Semi-processed, dried taro products are stored in bamboo baskets or cloth bags that are tied in a wooden structure placed above the earthen stove in the kitchen. The heat and smoke emerged during cooking prevents spoilage of these products and preserved for more than 10 months. This practice of taro preservation is followed by *Konyak* tribes in Nagaland. Young unfolded leaf, matured leaf, mother corms and cormels are the preferably consumed plant parts of many taro landraces. Tribals consume boiled taro corms/cormels (fresh/dried) during breakfast and dinner along with black tea. This boiled taro food provides instant energy as well as reduces the rice consumption. Since the boiled corms and cormels are slowly digested, they provide energy for carrying out agricultural operations and keep them active for 3 to 4 hours.

Various cuisines prepared by tribal communities in North-Eastern states have been well documented (Sivakumar et al., 2013; 2019). The *Meitei* tribal community in Manipur prepares *pan irambo*, *pan thongba*, *uti curry*, *hawaijar panthongba* and *shingzu* from taro plants (Sivakumar et al., 2013). The *Paite* tribal community in Manipur prepares *dolhou*, *uti chutney*, *Balkan* and *monglok curry* from taro plants. The *Kuki* tribal community in Manipur prepares *hinjang* (big taro), *palu-kabi shi shingzu* and *palu-kabi curry* from taro plants. *Maring* tribal community in Manipur prepares *pan thongba* (taro curry), *pan arouba*, and *chagempomba* from taro plant). The *Konyak* tribal community in Nagaland prepares semi-processed food such as *teangwan*, *fluo*, *shouhwan*, *tunggan* (dried taro corms/cormels), *teangyakhoi*, *teanghoi*, *teang*, *fluo curry*, *tung rahak sui*, *tungkungsui*, *tungrhak*, *tunkhon*, *tung pai*, *tungkhai*, tunguhok from taro plants. *Ao* tribal community in Nagaland prepares *Anishi* from taro leaves.

Various Indian cuisines prepared from taro plants in different states across India have been documented (Sunitha et al., 2016). In Andaman and Nicobar Islands, taro (*ghuniya*) leaf chatni, taro cake and taro chips are prepared from taro. In Himachal Pradesh, *taro pathrode* (taro leaf rolls) and *bari* (taro nuggets) are prepared from taro. In Kerala, *taro asthram*, *taro pulingari*, boiled taro, *taro thoran*, taro fry, *taro petiole kalan*, taro curry, taro chips, taro petiole curry are prepared. In Maharashtra, *aluche fadafade* (taro *fadafade*) is prepared from taro leaves. In Manipur, ooti asangba (green ooti), is prepared from taro leaves. In Manipur, *Ooti asangba* (green ooti), *singju*, *bora* (pakora), *pan ahhajinggathongba* (taro cooked with shrimps) are prepared from taro leaves. In Meghalaya, *shet sboh ka shrew bad u ktung* (taro with fish curry) is prepared from taro corms. In Tripura, taro with dry fish/fish head curry, *kacho sag* from swamp taro or semi-wild taro petiole, swamp taro or semi-wild taro stolon with dry fish, and semi-wild taro flowers with dry fish are prepared from taro plants.

Taro flour-based gluten-free cookies

India is one of the largest biscuit producers in the world, and the bakery industry has been projected to grow annually at the rate of 15-17% (Kar et al., 2012). Being one of the most acceptable snack foods by children and adults, cookies/biscuits could be considered the best nutritional supplements. Coeliac disease (CD) is a chronic autoimmune disorder, estimated to affect approximately 1-2% of the world population, and results from dietary intolerance to gluten. Ingestion of gluten by celiac patients causes villous atrophy of the small intestine and leads to cramping, bloating, diarrhoea, weight loss, vitamin and mineral deficiencies etc. The disease has reached alarming proportions in Europe and the USA and India. Celiac patients cannot consume cookies made from wheat flour which contains gluten. In search of alternative non-wheat flours for preparing cookies taro flour could supplement wheat flour. Taro flour-based gluten-free cookies suitable for celiac patients with overall sensory acceptability could be prepared by creamery method using taro flour (50%), rice flour (25%), sorghum flour (15%) and cassava flour (10%) (Giri and Sajeev, 2020). Spread ratio of taro flour-based gluten-free cookies varied between 3.95 and 5.49, and it decreased with increasing level of taro flour. Breaking hardness and toughness of different cookies decreased with increasing level of taro flour in flour blends. Minerals content in taro flour-based gluten-free cookies was higher than maida-based cookies. Gluten-free cookies prepared with taro flour had the maximum crude fiber content as compared to maida-based cookies.

Starch

The chemical composition and hence, the physicochemical properties such as water absorption capacity, water solubility index and other properties of taro starch vary with location and cultivar/variety differences (Moorthy et al., 2003; Sit et al., 2014 a, b). The starch content of taro varies from 12-25% for different varieties available in India (Edison 2006; Saikia et al., 2012; Sit et al., 2013, 2014 a, b). Taro starch yield increased by enzymatic isolation method compared to conventional method (Sit et al., 2015). *Eddoe* taro starch yield was highest (17.22 %) when both cellulase and xylanase concentrations were 300 U/100 g tuber, at 35°C and 2 h incubation time. *Eddoe* taro starch yield was highest at high concentration of cellulase or xylanase and incubation time was the minimum. This indicated that less time is required to hydrolyze the cell wall components when concentrations of the enzymes are high. The effectiveness of xylanase in increasing the recovery of starch from taro tubers also indicates that xylan is also an important component of the cell walls of taro corms/cormels, and degradation of xylan is necessary for releasing starch granules from the cells of taro. *Eddoe* taro starch yield increased with increase in concentration of both the enzymes as well as combination of the two enzymes. *Eddoe* taro starches exhibited broader range of gelatinization compared to dasheen starches, which may be attributed to the higher amylose content of these starches (Sit et al., 2013). Enzymatic isolation of *eddoe* taro starch has no adverse effect on the pasting properties of the starch. The pasting properties of the *eddoe* taro starches evinced no significant differences in pasting temperature, PV, HV, FV, SV and BV values, although the pasting temperature was slightly higher and viscosities were lower in the starch pastes isolated by enzymatic method compared to the conventional method. This was attributed to the loss of amylose in an enzymatic method which might have increased the viscosity of the starch pastes (Sit et al., 2015).

Ultrasound has been used for increasing the recovery of starch from cereals like maize and rice or for modifying the properties of isolated starch. Starch yield from ultrasonic treatment varied from 17.45 to 18.97% compared to 15.29% in the conventional method. The highest yield of 18.97% was obtained with treatment time of 10 min, treatment cycle 0.5, and amplitude of 50%. Swelling, solubility, pasting, and texture properties of the ultrasonically extracted starch significantly increased. A slight decrease in clarity of the starch pastes was also observed after ultrasonic pre-treatment, but the differences were insignificant. Freeze-thaw stability of the ultrasonically extracted starches was found to be better compared to starch extracted using conventional method, making them suitable for foods subjected to refrigeration. The whiteness of the ultrasonically extracted starch powders was lower compared to conventionally extracted starch, but the differences were not statistically significant (Sit et al., 2014c).

Starch granules of taro are smaller in size and the starch has lower viscosities compared with other tuber starches with lesser breakdown at higher temperatures and could be used as thickeners in products where prolonged heating and stirring is required like sauce, soups, baby foods etc. (Lakhanpaul et al., 2003; Sit et al., 2014b). Due to the small granule size of taro starch, it has been considered to be easily digestible; hence it is widely used in baby foods and the diets of people allergic to cereals and children sensitive to milk. The *in vivo* digestibility of taro starch was comparable with corn starch (Moorthy, 2002).

Utility of taro starch has been well documented (Ahmed and Khan, 2013; Sit et al., 2014b). The application of a given starch is decided by its physicochemical and functional properties. Factors such as farming practices and differences in cultivar among taro may affect their chemical composition and hence, the physicochemical properties of the starches.

Taro starch is considered to be easily digestible because of the small size of its starch granules; hence it is widely used in baby foods and the diets of people allergic to cereals and children sensitive to milk. The *in vivo* digestibility of taro starch was found to be comparable to corn starch (Moorthy, 2002) and was more susceptible to pancreatin hydrolysis than other tuber and root starches. Due to ease of assimilation, taro starch can be used by infants and persons with digestive problems. Due to its small granule size, it is suitable for many industrial applications and forms smooth textural gel. Its starch can be used in the preparation of biodegradable polyethylene film and can act as a fat substitute due to its small granule size. They can also be used for entrapment of flavouring compounds like vanillin. The small size of granules makes it ideal in cosmetic formulations like face powder and in dusting preparations that use aerosol dispensing systems. Despite the above-mentioned uses, large-scale extraction and utilization of taro starch are not practiced.

The physicochemical, functional, textural and color properties of starches of Indian taro varieties have been studied (Saikia et al., 2011; Kaushal et al., 2012; Kaur et al., 2013; Sit et al., 2013, 2014a, b). The physicochemical, functional, textural and color properties of starches from taro varieties of two different types [*Ahina, Muktakesi, Kani* (*eddoe* types) and *Garu, JCC37, JCC57* (*dasheen* types)] were characterized and compared with maize, potato and rice starches (Sit et al., 2013, 2014 a, b). The yield of starch from *eddoe* and *dasheen* taro, and potato were 9.2, 11.6, and 12.9 g per 100 g fresh corms, respectively. The lower starch yield of taro tubers compared to that of potato was attributed to the presence of mucilaginous materials in taro tubers which resisted settling of the starch granules. The moisture content of the starches varied from 10 to 11.3% and was within safe limit for storage of starches without deterioration in quality of starches.

The protein content of *eddoe* taro starch (*Panchamukhi*) was lower (0.34%) as compared to maize starch (0.64%) and was statistically different. The protein content of rice starch (1.3%) was significantly higher than taro and potato starches (Sit et al. 2013, 2014a, b). Starch granules in rice grain are embedded in protein matrix which was difficult to separate from the granules and might have contributed to the protein content of rice starch. The fat and fiber content of the starches were very similar with slight differences between the samples. There were no significant differences between the ash content of the isolated starches from taro, potato, and rice. The ash content of *eddoe* taro (*Panchamukhi*) and maize starch was found to be 0.09 and 0.07% respectively. The lipid content of *eddoe* taro (*Panchamukhi*) taro and maize starch was found to be 0.11 and 0.24% respectively (Sit et al., 2013, 2014a, b).

The purity of the isolated starches from *eddoe* and dasheen taro were 96.2 and 96.0%, respectively which were less as compared to potato starch with a purity of 97.1% and rice starch with a purity of 95.7%. This was attributed to high amount of mucilage in taro tubers compared to potato, and separation of starch from starch water containing mucilage becomes difficult, but the differences are not significant.

Amylose content

The amylose content of starches of *eddoe* type of taros (*Kani*, *Ahina* and *Mukatakashi, Pachamukhi*) was higher (14.8-18.14%) than *dasheen* (11.9-13.2%) (*Garu*, JCC37 and JCC57) types (Sit et al., 2013, 2014 a, b). In other studies, amylose content of starch of eddoe taro variety namely *Ghee Kochu* was 15.14% (Saikia et al., 2011) and 17.54% (Saikia et al., 2012). The amylose content of the taro starches was significantly lower than maize, potato and rice starch with amylose content of 24.2, 25.8 and 21.6%, respectively (Sit et al., 2013, 2014 a, b). The low level of amylose makes taro starches more hydrolysable. Starch with high level of amylose hydrolysed more slowly than starch with low level of amylose owing to the double-helical form of amylose molecule which is not easily accessible by enzymes.

Starch granules size

Starch granules from the two varieties of taro and that of rice are polygonal and irregular in shape while that of potato were oval or spherical (Saikia et al., 2011, 2012; Sit et al., 2013, 2014b, c; Pachuau et al., 2018). Average granule size of the taro starches was much smaller than maize and potato starch, but comparable to the rice starch. The size of taro starch granules varied from 1.19 to 4.17 and 1.43 to 4.88 μm, respectively for *eddoe* and dasheen taro (Sit et al., 2013, 2014a, b; Pachuau et al., 2018). In another study, size of starch granules varied between 0.5 and 3.5 μm (Saikia et al., 2011). The size of rice starch granules varied from 2.3 to 6.6 μm, while that of potato starch varied from 7.6 to 47.6 μm and maize starch varied between 7.38 and 16.67. Maize starch was found to have irregular, round or oval shapes with a diameter ranging from 7.38 to 16.67mm (Sit et al., 2013, 2014a, b). Size of starch granule influences physicochemical and functional properties of starches like paste, viscosity, swelling volume solubility and digestibility (Moorthy et al., 2003). Swelling of large granules was found to be higher compared to smaller granules which also affected the viscosity, as swelling is directly related to increased viscosity. Citration of the taro starch with 40% citric acid slightly increased granule size which was attributed to swelling as a result of incorporating water when citric acid is added for reaction (Pachuau et al., 2018).

Properties like digestibility and retrogradation are evinced by XRD pattern of the starches. Generally, tuber starches have B or C-type patterns. However, X-ray diffraction pattern revealed that starches of both *eddoe* and dasheen taro had an A-type pattern similar to rice starch, which is characteristic of cereal starches while potato starch had a B-type pattern (Saikia et al., 2011, 2012; Sit et al., 2013, 2014a, b). Starches with A-type structures are more tightly packed, have higher melting points and more stable compared to starches with B-type XRD patterns. The Fourier transform infrared (FT-IR) spectra of all the four starches were almost similar.

Pasting temperature

The pasting temperature of *eddoe* starch was highest and significantly different from the other starches. Starch from *eddoe* taro had highest pasting temperature (74.4-88.3°C), followed by dasheen taro (82.1°C), rice (78.4°C) and maize (69.7°C) (Sit et al., 2013, 2014a, b). The pasting temperature of potato starch was found to be significantly lower at 68.8°C. The peak viscosity, hold viscosity and final viscosity of *eddoe* starch was lowest among the starches but were close to dasheen taro and rice starches, but much lower than potato starch. The higher pasting temperature and lower values of final viscosity, breakdown viscosity and setback viscosity of *eddoe* taro starch indicate that it could be used as stabilizers or thickeners in food products that are subjected to heat at higher temperature and change in viscosity is not desirable during heating and cooling. The pasting temperature of the *eddoe* taro starch paste was slightly higher and viscosity was lower for the starch isolated by the enzymatic method compared to conventional method (Sit et al., 2015).

Gelatinization temperatures

The peak gelatinization temperatures (T*p*) of starches of *eddoe* and dasheen taro were 70.61-74.7 and 74.1-83.33°C respectively (Sit et al., 2013, 2014b). In another study, peak gelatinization temperature of taro starch was at 88.1/106.97°C (Saikia et al., 2011, 2012). The T*p* for rice starch was 72.5°C, and for potato starch it was 65.6°C. The differences in the thermal behavior of the starches were attributed to the amylose content and crystallinity of the starch granules as both taro and rice starches had A-type XRD patterns. The thermal properties of the starches were related to the granule size and degree of swelling of the starch granules. The gelatinization behavior of the taro starches was comparable to rice starch but were much different from potato starch. Taro and rice starch being smaller in size than potato starch, swelled lesser and therefore had higher gelatinization temperature (Sit et al., 2014b). Citrification of taro starch with 40% citric acid reduced peak gelatinization temperature from 101.01°C to 72.5°C (Pachua et al., 2018).

Swelling property

The swelling property of *eddoe* and dasheen taro starches varied from 2.37 to 13.49 g/g and 2.3 to 13.7 g/g of starch, respectively when the temperature increased from 60°C to 90°C (Sit et al., 2013, 2014a, b). The swelling property of *eddoe* taro was higher than *dasheen* taro at 60, 70 and 90°C, but at 80°C the swelling power of *dasheen* taro was highest (Sit et al., 2013). The swelling property of maize starch it varied from 3.43 to 11.31 g/g, when temperature was increased from 60 to 90°C (Sit et al., 2014a). For potato and rice swelling power varied from 2.5 to 36.8 and 3.3 to 12.6 g/g of starch, respectively with an increase in temperature (Sit et al., 2014b). At 60°C the differences in swelling power of all the starches were not significantly different. But as the temperature increased potato starch swelled significantly higher compared to other starches investigated. Swelling of taro starches was not significantly different from each other at all temperatures and was comparable with that of rice starch. The reason for higher swelling power of potato starch was attributed to the large size of the starch granules and higher amount of phosphate present in potato starch. The swelling of the *eddoe* taro starch granules increased for enzymatic isolation method (14.95 g/g) compared to conventional isolation method (13.32 g/g) (Sit et al., 2015). Citration with 40% citric acid slightly affects the swelling of the taro starch as the degree of swelling was reduced from 6.02 in the purified taro starch to 5.89 in the citrate taro starch (Pachua et al., 2018).

Solubility

The solubility of the taro starch in water increased significantly with increase in temperature and the solubility of the starches at 90°C were much higher than at 80°C (Sit et al., 2013, 2014b). The solubility of *eddoe* taro (*Panchamukhi*) maize starches varied from 5.03 to 22.47% and 4.05 to 15.76% respectively (Sit et al. 2014a). The solubility of the four starches (*eddoe* and *dasheen* taro, rice and potato) were not significantly different at temperature up to 80°C, but at 90°C the solubility of the taro starches was significantly higher than those of potato and rice starch, which was attributed to the very small size of the starch granules. The highest solubility was recorded for dasheen taro at 80 and 90°C. The *eddoe* taro had lower solubility compared to dasheen taro at 80 and 90°C. The low solubility of starches at low temperatures was attributed to the semi-crystalline structure of the starch granules and the hydrogen bonds formed between hydroxyl groups within the starch molecules. As the temperature increased, the solubility increased due to breaking of starch granules and exposure of hydrophilic groups to water. Solubility of *eddoe* taro starch decreased for enzymatic isolation method (19.1%) compared to conventional isolation method (20.2%) (Sit et al., 2015)

Firmness

The firmness of the taro starch pastes varied between 11.6 and 11.9 g for both *eddoe* and *dasheen* taro cultivars, while that for rice starch paste was 11.38 g (Sit et al., 2013, 2014a, b). The firmness of taro and rice starch pastes were not much different but were significantly lower than potato starch paste with a firmness of 13.5 g. Similar trend was observed with consistency and cohesiveness of the starch pastes. The consistency of taro starch (220 g.s.) is significantly lower than the potato starch and at par with rice starch. This was presumably attributed to smaller granule size and lower viscosity of the taro starch. Taro starch pastes could be used in place of rice starch in many food applications as the texture properties of taro starch pastes were very similar to that of rice starch. Dasheen taro starches had higher viscosity than eddoe taro starches (Sit et al., 2013). Taro starch was found to be better in comparison to maize starch in many food applications where prolonged heating and stirring are required like sauces and soups, and retrogradation is not desirable. Studies by (Sit et al., 2014a) revealed that *eddoe* taro starch can be used as thickener in products requiring prolonged heating and stirring. Texture, color and sensory evaluation of the tomato ketchup incorporated with *eddoe* taro starch showed significant increase in the texture properties like firmness and consistency without affecting the color and were comparable to maize starch.

Flour

Production of stable products like flour by use of cheaper drying methods can minimize postharvest losses and enhance the utilization of such underutilized taro corm/cormels into processed products. Quality taro flour can be produced from the slices cooked in water for 10 min followed by drying at 60°C in tray dryer (Kumar et al., 2018). Taro flour has a good potential to be used in food industry either for development of new food products or for the replacement of current food products made from conventional flour sources (Kaushal et al., 2012; Kaur et al., 2013). Taro flour is utilized for the production of chips and cake (Kumar et al., 2015, 2018), noodles (Kaushal and Sharma, 2014). Flour can also be utilized for food industry and other industries like textile, drug and paper industries (Sharma and Kaushal, 2016). The chemical composition and functional properties of taro flour differed significantly from flours of soya, potato, corn, rice and pigeon pea. Taro flour significantly differed from other flours in exhibiting highest carbohydrate, water absorption, and lower protein, foaming capacity and setback viscosity. Swelling power of flours is related to their protein and starch contents. High protein content in flour may cause the starch granules to be embedded within a stiff protein matrix which subsequently limits the access of the starch to water and restricts the swelling power. The low protein and high carbohydrate content of taro flour resulted in their higher swelling ability. High viscosity, water-absorbing capacity and lowest foaming capacity make taro flour a good thickener or gelling agent in various food products. The paste formed by taro flour as a result of heating was stable upon cooling as was evident by its lower setback viscosity. This is advantageous in formulations where starch stability is required at low temperatures.

Medicinal value

The popularity of herbal medicine in recent times is increasing based on the premise that plants contain natural phytochemicals that can prevent diseases and promote health. Taro leaf extract has been proved to be a medicinal remedy for the treatment of various health issues. All the taro plant parts *viz*., leaves, petiole and corm/cormels have different medicinal properties (Kirtikar and Basu, 2005; Pawar et al., 2018; Keerthy and Joshi 2019; Gupta et al., 2019). Taro leaves as well as yellow-fleshed corms have significant levels of phenolic flavonoid pigment antioxidants such as ß-carotenes, and cryptoxanthin along with vitamin A. One-hundred-gram fresh taro leaves contain 4825 IU or 161% of RDA of vitamin A. Altogether, these compounds are required for maintaining healthy mucus membranes, skin and vision. Consumption of natural foods rich in flavonoids helps to protect from lung and oral cavity cancers. Taro leaf stalk extract with salt is used as an absorbent in cases of inflamed glands and buboes. Extract of the petiole is stypic. Taro corm is one of the finest source dietary fibers; 100 g taro corm provides 4.1 g or 11% of daily requirement of dietary fiber. Together with slow-digesting complex carbohydrates, moderate amounts of fiber in the food helps gradual rise in blood sugar levels. Taro corms provide healthy amounts of some important minerals like zinc, magnesium, copper, iron, and manganese. In addition, the corm has very good amounts of potassium important component of cells and body fluids that help regulate heart rate and blood pressure. Decoction of the peel is given as a folk medicine to cure diarrhea. Consumption of taro increases body weight, prevents excessive secretion of sputum in asthmatic individuals. Internally, it acts as a laxative, demulcent, anodyne, galactagogue and is used in cases of piles and congestion of the portal system; also used as an antidote to the stings of wasps and other insects. People of the Munda tribe traditionally use corms of taro as remedy for body ache. The extract from taro corm is used in alopecia, as an expectorant, stimulant, appetizer and astringent. When cooked, the vegetable contains mucilage and found to be an effective nervine tonic (Pawar et al., 2018). The extract of the plant leaf is rubefacient, stimulant, styptic and is useful in internal hemorrhages, adenitis, otalgia and buboes. The corm extract is demulcent, laxative and anodyne. Taro leaves have been found to exhibit antihelminthic, anti-diabetic and anti-inflammatory activity (Chatterjee and Chandrapakrashi, 2001; Arora et al., 2011; Pawar et al., 2018). Leaf extract of the plant also finds its application in scorpion stings, in snake bites, in food poisoning from plant origin, etc. The plant is used in Ayurveda formulations for ailments *viz*., constipation, alopecia, stomatitis, hemorrhoids and general weakness (Devarkar et al., 2011).

Antimicrobial properties

The aqueous extract of taro leaf at 400 mg/ml exhibited antimicrobial activity against gram-positive bacterial strain *Salmonella mutants* and gram-negative bacterial strain *Klebsiella pneumoniae*as indicated by the zone of inhibition. The inhibition effect of taro leaf extract was at par or 50% of the effect of antibiotic chloramphinical (200 g/ml) (Singh et al., 2011). *Staphylococcus aures*, the methicillin-resistant microbe can be effectively controlled with the application of the synergistic therapy of gentamicin (1.25 mg/ml) plus the aqueous leaf extract (30 mg/ml) of taro (Blesson et al., 2015). The taro leaf extract and antibiotic individually didn't show good antibacterial activity against the bacteria. The activity of gentamicin increased up to 10-fold when the combined mixture of taro leaf extract and antibiotic was used against the bacteria. The synergistic mixture with combination of gentamicin and aqueous taro leaf extract had larger diameter (zone of inhibition = 29 mm) when compared to the individual activity of gentamicin (zone of inhibition = 17 mm) and aqueous taro leaf extract (zone of inhibition = 0 mm). The aqueous taro leaf extract could serve as a source of potential adjuvant for gentamicin. Here, the alkaloids, flavonoids, or any other compound present in the taro leaf extract binds to the cell wall of the MRSA, increase the permeability of the cell wall and enhance the flow of antibiotic into MRSA and enhanced the antibacterial activity. Methanol extract of taro leaf as well as corm had antimicrobial activity measured by the zone of inhibition against nine clinical pathogens both Gram-positive *viz*., *Staphylococcus aureus*, *Enterococcus* sp. and Gram-negative bacteria, *viz*. *Proteus mirabilis*, *Pseudomonas aeruginosa*, *Serratia* sp., *Escherichia coli*, *Shigella* sp., *Salmonella* sp., *Klebsiella* sp., and (Chakraborty et al., 2015). Highest zone of inhibition was observed at 100 mg/ml concentration against *Klebsiella* sp. for tuber extract while leaf extract showed highest activity at 100 mg/ml concentration against *Proteus mirabilis*. In comparison to leaf extract, corm/cormel extract had higher antimicrobial activity. Taro corm and leaf extract had moderate anticancer activity against human osteosarcoma cell line. Percentage of cell viability decreased at high concentration (200 mg/ml) of extract.

Ethanol extract of taro leaves exhibited antibacterial activity against *Staphylococcus aureus*, *Klebsiella sp*, *Escherichia coli* and *Pseudomonas aeruginosa* and antifungal activity against *Candida albicans* in dose-dependent manner (Dutta and Aich, 2017). The zone of inhibition of bacteria as well as the fungus increased with increase in taro leaf extract between 50 and 400 mg/100ml concentration and the highest effect was recorded with 400 mg/100ml. In the case of bacteria, the effect of taro leaf extract at 400 mg/ml was nearly 50% of the effect of antibiotics (gentamycin and ceftazidime) as indicated by the zone of inhibition. Ethanol extract of taro leaf exhibited antibacterial activities against *Pseudomonas aeruginosa*, methanol and water extract of taro leaf had antibacterial activity against *E. coli,* whereas taro leaf extract with all the three solvents had antibacterial activity against *Salmonella typhi*, *Klebsiella pneumonia* and *Bacillus subtilis* (Dhanraj et al., 2013).

Lipid-lowering property

Taro corm has hypolipidemic and antihyperlipidemic (lipid-lowering) properties due to the presence of mannose-free arabinogalactan mucilage containing galactose and arabinose in the ratio 2:1 (Boban et al., 2006). Taro corm had one gram mucilage per 100 g dry cornflour and mucilage contained 90% carbohydrate and 5% protein without starch. Total cholesterol and triacylglycerols decreased in serum and tissues of liver and aorta of mice fed with taro mucilage at a dose of 4 mg/100 g body weight per day for 8 weeks. The synthesis and secretion of apoB-containing lipoproteins, mainly VLDL, by hepatocytes isolated from livers of mucilage-fed rats and serum triacylglycerols decreased whereas HDL/VLDL þ LDL ratio increased as compared to control. Liver cholesterol, triacylglycerols and aortic triacylglycerols decreased significantly while aortic cholesterol did not decrease. Neutral sterol and bile acids excretion significantly increased in mice fed with taro mucilage and this was suggested to be due to the decrease in absorption of cholesterol or fatty acids and decrease in reabsorption of biliary cholesterol and bile acids in the gastrointestinal tract. The hypocholesterolaemic effect of soluble fiber such as taro mucilage relates to its gel-forming property which is associated with its viscosity and water holding capacity.

Antioxidative property

Biochemical and histopathological studies (Archana et al., 2018) revealed hepatoprotective potential of 70% methanolic extract of taro leaves by chelating the free radicals in iron overload-induced mice. In vertebrates, although an optimum level of iron is always maintained by cells to balance between essentiality and toxicity, in some situations like hemochromatosis disease, the balance is disrupted which results in iron overloaded toxicity. Iron overload is either genetically inherited or acquired by several conditions such as frequent transfusion, abused consumption of iron and chronic hepatitis that have potential to cause acquired iron overload. High level of iron absorbed in small intestine and is accumulated in liver, pancreas and in some parts of brain causing impairing of the vital metabolic function of these organs. Iron overload-induced *in vivo* is characterized by excessive deposition of ferrous ions in liver cells which undergo oxidative damage resulting in cell death. Different iron chelators implicated in treatment of iron overload have been evaluated and each of these chelators had its own advantages and disadvantages. Taro leaf extract at the rate of 200 mg/kg body weight with significant level of bioactive phytoconstituents (phenolics and flavonoids) had hepatoprotective activity by upregulating antioxidant enzymes and chelating iron to excrete from the body. Iron-overloaded hepatic damage led to the leakage of cellular enzymes and increased levels of serum markers such as ALT (196%) and AST (148%) in the bloodstream. After orally treating iron overloaded mice with taro leaf extract (200 mg dry /kg body weight) levels of these enzymes were restored whereas antioxidant enzymes [catalase (CAT), superoxide dismutase (SOD), glutathione-S-transferase (GST)] activity increased. Thus, taro leaf extract is a potential iron-chelating drug in the treatment of iron-overloaded diseases.

Anti-inflammatory property

Biren et al. (2007) investigated anti-inflammatory effect of the ethanol extract of the leaves of taro in Wistar rats using the carrageenan-induced left hind paw edema, carrageenan-induced pleurisy, and cotton pellet induced granuloma model. The ethanol extract of taro leaf (100 mg/kg, p.o.) inhibited carrageenan-induced rat paw edema. It inhibited leukocyte migration, reduced the pleural exudates, and reduced the granuloma weight in the cotton pellet granuloma method. The results indicated that the ethanol extract produced significant anti-inflammatory activity when compared with the untreated control.

Anti-diabetic property

The blood-glucose-lowering effect of the ethanol extract of taro leaf was demonstrated in alloxan induced diabetic mice (Kumawat et al., 2010). Taro leaf extract (100, 200 and 400 mg/kg body weight) and metformin (450 mg/kg body weight) were administered orally in alloxan (120 mg/kg, i.p.) induced diabetic mice. In acute study, with all doses of taro leaf extract, onset of reduction of blood glucose was observed at 2 ha and the effect was highest with 400 mg/kg body weight. Administering 400 mg/kg body weight of taro leaf extract reduced blood glucose level to 310 mg/dl at 2 h from the initial value (330 mg/dl), peaked at 6 h (210 mg/dl) but anti-hyperglycemic effect diminished at 24 h. In subacute study, maximum reduction in blood glucose was observed (156 mg/dl) on 14th day when taro leaf extract (400 mg/kg body weight) was administered once a day for 14 days. Administering taro leaf extract (400 mg/kg) also prevented loss of body weight. The changes in blood glucose level in both acute and subacute studies, as well as body weight due to administering taro leaf extract were at par with the effect of metformin. This antihyperglycaemic activity of taro leaf extract demonstrated in alloxan-induced diabetic mice suggests taro leaf as a potential medicine for diabetes. The antiurolithiatic activity of 90% methanol taro leaf extract was demonstrated in experimental kidney stones (calcium oxalate stones) (Dwivedi et al., 2016).

Neuropharmacological properties

The neuropharmacological properties (such as antidepressant, anxiolytic, sedative, and smooth muscle relaxant activity) of hydroalcoholic extract of taro leaves were demonstrated using several experimental models in Swiss albino mice (Kalariya et al., 2010, 2015). Rats and mice spontaneously bury unpleasant, harmful and noxious materials present in their environment to avoid and protect from the localized threat. Obsessive-compulsive disorder (OCD is the neuropsychiatric/ anxiety disorder associated with major depression. Spontaneous burying of glass marbles by mice reflecting anxiety state of mice simulates some aspects of OCD. Inhibition of marble-burying has often used an index of anxiolytic drug action and used to evaluate anti-compulsive drugs in the Marble-burying test (Kalariya et al., 2015). The taro leaf extract (25, 50 mg/kg, p. o.) showed a dose-dependent significant reduction in the number of marbles buried as compared with untreated, control mice. The effect of taro leaf extract was attributed to flavonoids, steroids and b-sitosterol present in taro leaves. The effect of taro leaf extract was 50% of the effect of fluoxetine (5 mg/kg, i.p.) - a reference standard drug used in the treatment of the obsessive-compulsive disorder. The taro leaf extract administered at 100, 200 and 400 mg/kg body weight significantly reduced duration of immobility in a dose-dependent manner in the Westar albino mice behavior despair test (Kalariya et al., 2010). This antidepressant effect of taro leaf extract was at par with the effect of reference drug imipramine. Taro leaf extract at 50 and 100 mg/kg significantly reduced motor coordination and also prolonged sleeping time and the effect was nearly 50% of the effect of reference drug diazepam (Kalariya et al., 2010). Taro leaf extract significantly reduced total immobility time and enhanced struggling behavior in a dose-dependent manner, suggesting an antidepressant effect and flavonoids present in taro leaf was attributed for the antidepressant effect.

Antihypertensive properties

Administering aqueous extract of taro leaves had antihypertensive effect on mice (Vasant et al., 2012). In this study, a significant decrease in blood pressure (systolic, diastolic, mean arterial) was observed in the renal artery occluded, noradrenaline administered hypertensive mice after treatment with aqueous extract of taro leaves at doses of 200 and 400 mg/kg body weight. Administering of 100, 200, and 400 mg/kg/day, p.o. aqueous extract of taro leaves for six weeks and 10, 20, and 40 mg/kg on the day of experiment in renal artery-occluded hypertensive mice and 20 and 40 mg/kg in noradrenalin induced hypertension in mice produced significant anti-hypertensive effects. The effect of taro leaf extract was at par with the effect of the drug captopril1. Administering aqueous extract of taro leaves (400 mg/kg, p. o.) showed positive diuretic activity at 5 h. Administering aqueous extract of taro leaves (200 and 400 mg/kg, p. o.) significantly increased sodium and chloride content of urine in 5 h and 24 h and additionally potassium in 24 h urine. The effect was attributed to the inhibition of the angiotensin-converting enzyme (ACE), or the inhibition of phosphodiesterase, or the vasodilation resulting from the release of endothelium-derived relaxing factor, β-blocking, and/ or Ca^{2+} channel blocking activities which were reported for the phytoconstituents, specifically flavonoids such as vitexin, isovitexin, orientin, and isoorientin present in the taro leaves.

Utility in drug industry

Pharmaceutical industry utilizes biological macromolecules such as polysaccharide gum, mucilage and starches in the manufacturing of drugs to improve their stability, modulate the release and enhance the bioavailability while also facilitating patient acceptance. Naturally occurring polymers, being biocompatible and biodegradable, are currently extensively researched for the development of novel drug delivery systems. Oral route is the most favorable route of drug delivery and oral controlled release formulations are in demand because of their benefit *viz*., patient compliance and therapeutic advantages. The main obstruction in the development of controlled release formulation is short gastric resident time. Number of drugs like domperidone, ranitidne, theophylline has narrow absorption window from upper intestine i.e., stomach and small intestine. Due to short gastric resident time less than 6 hr these drug reaches the non-absorbing distal parts of intestine. Therefore, main challenge is to prolong the resident time of drug in stomach and proximal small intestine. Gastro retentive drug delivery techniques are primarily controlled release drug delivery systems, which get retained in the stomach for longer period, thus helping in absorption of drug for the intended duration of time. It helps to improve bioavailability, reduces drug wastage, improves solubility of drugs that are less soluble in high pH environments (e.g., weakly basic drugs like domperidone, papaverine). Mucoadhesion is the bioadhesion to the stomach mucus or a mucous membrane in which two materials, at least one of which is biological in nature, are held together for extended periods by interfacial forces. The gum/mucilage as well as starch obtained from the taro corm is an effective binder and mucoadhesive matrix-forming agent (Pawar et al., 2015). Arora et al., (2011) formulated and evaluated oral controlled release mucoadhesive matrix tablets of taro mucilage/gum incorporating domperidone as model drug. Mucoadhesive strength increased from 13.673 to 23.287 and from 40.378 to 67.519 at low (10% w/w) and high levels (30% w/w) of taro gum respectively, as the concentration of polyvinylpyrrolidone (PVP) increased from 5 to 15% (w/w) (PVP provides more tensile strength and prevent the tablet from disintegration and stay it firm). Taro gum had direct effect on release of drugs by formation of matrix and at higher concentrations. The time for 50% drug release value (t_{50}) increased from 50 to 58 min and from 122 to 220 min at low and high levels of taro gum respectively, as the concentration of PVP increased. *In vitro* drug release profile showed decline in drug release from 77.02 to 67.57%, which suggests release retardant effect of taro gum with the increasing concentration of PVP K 30. This study showed concentration-dependent mucoadhesive and release retardant potential of taro mucilage/gum in the formulation of gastro retentive mucoadhesive matrix tablets.

Starches are used for a long time as excipients in pharmaceutical preparations. Mainly maize, potato and wheat starches are used and monographed in several pharmacopeias. The native starches/modified (pregelatinized) are used as fillers and disintegrants in tablets and fillers in dermatological powders. Also, starches have been used as filler-binders in tablet technology. In the preparation of tablets; starch disintegrants are generally incorporated in the concentration range of 2-10% to facilitate fragmentation and subsequent dissolution. This abrupt and thorough de-aggregation can result in quicker absorption and a faster onset of the desired effect. Taro polysaccharide can be used as a disintegrant in the formulation of orally disintegrating tablets. Its disintegrating property was comparable with that of the commercially available super-disintegrants. Native starch and gums isolated from taro have been widely investigated as pharmaceutical excipients (Deepika et al., 2013; Kusuma et al., 2015; Sarkar et al., 2015; Arora et al., 2015). Taro starch is a better disintegrant as compared to the other natural starches viz., potato and corn starch placebo tablets (Ahmed and Khan 2013; Pachuau et al., 2018). Paracetamol release from the tablet was retarded in simulated gastrointestinal media up to about 8 hours when 4.7% taro starch was used in tablet formulation (Deepika et al., 2013). Taro starch was also found to be comparable to the standard maize starch as disintegrant in tablet formulation (Kususma et al., 2015). Incorporation of citrate taro starch (taro starch treated with citric acid at 40% weight of dry starch) in paracetamol tablet reduced disintegration time from 10 seconds to 81 seconds when the percentage of citrate taro starch in the formulation was increased from 2.5 % to 10% (Pachuau et al., 2018). The disintegration efficiency ratio, which is a measure of the balance between mechanical and disintegrant properties of tablets was also observed to increase in both taro starch and citrate taro starch from 1.36 at 2.5 % to 2.17 and 2.52 at 10% respectively. Dissolution efficiency (DE) indicates the bioavailability tends to increase with increasing percent of citrate taro starch as well as the standard corn starch in the formulation. More than 80% dissolution was achieved in both the standard corn starch and the new citrate taro starch-based paracetamol tablets (Pachuau et al., 2018). Surface tension and viscosity of the native taro starch were attributed to the binding property of the starch in the prepared tablets. Taro corm mucilage in combination with hydroxy-propyl-methyl cellulose (HPMC) was also successfully applied in the preparation of matrix-type transdermal patches for the delivery of diltiazem hydrochloride (Sarkar et al., 2015).

Challenges and Prospects of taro in India

Challenges

High yield coupled with high acridity of taro varieties is a challenge and warrants improvement of such varieties for these traits. The presence of oxalic acid in the form of oxalate crystals in some promising varieties and consumption of such varieties without adequate processing may lead to kidney-related illness. Shorter shelf life of fresh taro corms/cormels for 1 or 2 months may lead to loss of planting materials.

Prospects

The wide genetic diversity and genetic variability of taro germplasm offer great scope for developing and improving varieties for region-specific agroclimatic conditions. Taro is rich in carbohydrates, minerals and fibre can form an important affordable nutritional diet for South and Southeast Asian populations including SAARC countries.

SWOT analysis

Strength

- Leaves as good leafy vegetable.
- Leaves rich in minerals, vitamins and hormones.
- Relatively small starch granules facilitate easy digestion.
- Better prospects in value addition especially bakery products.
- Availability of lot of traditional cuisines/recipes with taro leaves especially among tribals.
- Mucilage is a good phyto antioxidant capable of reducing blood sugar (hypoglyceamic).
- Potential for use in pharmaceutical industries.
- Fetches high consumer price and equivalent to rice in livelihood generation.

Weakness

- Environmental conditions associated with flowering have not been studied.
- Non-flowering of varieties under some locations.
- Lack of variety in dasheen taro.
- Acridity of corms and cormels.
- Less peelability of skin of tubers in some varieties.

- Shorter shelf-life (1-3 months) of corms and cormels under room temperature.
- Lack of awareness of commercial potential of value-added products of taro.
- Lack of statistics on area, production, productivity and quantity exported.

Opportunities

- Potential of dual-use of the crop as tuber and leafy vegetable simultaneously.
- Scientific upscaling of the traditional recipes as a source of income generation for tribals.
- Popularization of taro as a nutritious leafy vegetable owing to its rich mineral and other micronutrient contents
- Breeding for specific objectives as for tuber alone and leaves alone can be thought of owing to the better acceptability of leaves as a leafy vegetable.
- Taking into account the utility of corms during some festivals nationally and internationally, large-scale production and export of taro can be done.
- Taking into account the physicochemical and other tuber biochemical quality attributes, the possibility of exploiting its potential in value addition especially in the confectionery industry can be given impetus.
- Anthocyanin rich purple taro genotype can be used for developing biofortified varieties.

Threats

- Vagaries of climate particularly drought can destroy the germplasm maintained at a single location. So, field-level germplasm maintenance shall be done at different locations.

Technologies

- Flower induction technique with chemicals such as GA3 and ascorbic acid.
- Regeneration protocol and rapid multiplication technique for eddoe and dasheen taro.

- TLB tolerant and high yielding varieties such as Muktakeshi, Pani Saru I, Pani saru II, Narendra Arvi-1, Narendra Arvi-2, Bidhan Chaitanya (BCC-1), Indira Arvi-1, Bhu Kripa, Bhu Sree exhibit resistance to leaf blight disease.
- Many high-yielding landraces of eddoe taro such as Thamarakkannan, Telia, Ahina Kochu and dasheen taro are available.
- Recipes for taro-based value-added products.

High impact technologies

- Recipes for taro-based value-added products.
- Taro varieties such as Muktakeshi, Pani Saru I, Pani saru II, Narendra Arvi-1, Narendra Arvi-2, Bidhan Chaitanya (BCC-1), Indira Arvi-1, Bhu Kripa, Bhu Sree exhibit resistance to leaf blight disease.

Recommendations

Despite of its nutritional, health, industrial and pharmaceutical importance, taro has not gained sufficient research attention to enhance its production potential. The use and consumption of taro corms/cormels are generally limited by the fact that they are prone to extensive post-harvest losses as the consequence of their high moisture content, sustained metabolism and microbial attack, leading to damage during harvest and storage. Nevertheless, the crop fetches a very good market price and is profitable equivalent to rice. As taro has great genetic diversity, there is a vast scope for its improvement. The future thrust areas for taro are:

1. Strengthening collaborative research among SAARC countries.
2. Morphological and molecular characterization of germplasm.
3. Exchange of unique germplasm, varieties among SAARC countries for mutual benefits.
4. Application of special breeding techniques such as polyploidy breeding, mutational breeding, somaclonal breeding and speed breeding for taro improvement.
5. Improvement of taro for TLB resistance, salinity tolerance, low acridity, β-carotene and anthocyanin.
6. HRD for Scientific and Technical personnel.
7. Establishing Farmer's cooperative societies for assisting farmers in marketing.
8. Although pharmacological properties of taro have been understood at laboratory level, its effect on human yet to be established through clinical trials.

9. The potential utility of taro starch in pharmaceutical and food industries needs to be popularized.
10. Popularization of value-added products from taro particularly chips from dasheen taro.
11. Establishment of Techno-incubation centers and capacity building of women self-help groups and small-scale entrepreneurs.

Conclusions

It is evident from the literature that extensive research has been done/in progress on taro improvement and utilization in India. As taro is highly remunerative crop compared to other vegetables, it has vast scope of expansion in India. Taro as a vegetable occupies an important niche in the food basket of Indian population. There are no biofortified varieties in taro and research is needed in this area. More varieties are to be released in dasheen taro as it has high yield potential and utilization aspects. Although, pharmaceutical values of taro have been realized, its worthiness needs to be clinically proved. The value-added products developed from taro need to be popularized. The SWOT analysis indicates that taro has a high scope in India. There is no authentic and dynamic record of area, and production of taro in India. Similarly, there is no record available on the quantum of taro export from India. Many promising, high-yielding genotypes/varieties, of taro and value addition technologies available in India, can be exchanged with SAARC countries for mutual benefits.

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Chapter 6

Status of Taro (*Colocasia esculenta)* for Sustainable Biodiversity and Nutritional Security in Maldives

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Abstract

The Maldives has a rich history of taro farming. Yet the cultivation practices have not changed significantly over the years compared to that of other crops. It has been mainly cultivated in the southern atolls. No significant advances have been seen in taro processing and value-addition. However, as the majority of taro is sold fresh, there is an immense potential for the development of value-added products. Additionally, taro is marked as a minor cash crop that caters to a small niche market. This is because taro products have not been used in regular staple food and have been competing with wheat and rice. Taro leaves are also not consumed. Hence, there is potential for the development of recipes and various dietary products as well. Taro production systems could be categorized as low-input and low-yielding that is based in a traditional integrated farming setting. As such, support services and related infrastructure are also not present in most growing areas. Moreover, production knowledge has been passed from generation to generation and most current producers are in the older age-group category. Nonetheless, this production system has prevented farmers from many pests and disease issues that have plagued the rest of the region. However, in recent years with increased movement of imported germplasm, soil-amendments, and compost between islands and remote areas, new pests and diseases have been surfacing. Consequently, the first cases of Taro Leaf Blight were reported in 2016. Major four (4) varieties have been cultivated throughout the country. They are distinguished based on morphological characteristics. There is a huge potential for improvement of the taro production system throughout the country. The development could be carried out in areas such as infrastructure, germplasms enhancement, support service creation, human resource capacity building, and promotion and investments in value-addition activities.

Introduction

Taro has been cultivated for hundreds of years in the Maldives islands as a staple food. The cultivation system of Maldives is a bit unique in that there are not many examples of taro grown in swamps with predominantly vertical water movement. In other countries such as the Cook Islands, Palau, and Fiji, swamp cultivation involves horizontal water movement between taro fields. In the Maldives, there is intensive, continuous cultivation, dating back many generations (Grahame, 2008). The production activities are more prominent in the southern atolls where natural swamps and land depressions have been used for cultivation. Livelihoods in these islands have been deeply integrated into the production activities and subsequently, most of the value-addition techniques arose from this region. During the Second World War, the inhabitants of southern islands fared well due to their skills and resources in taro production. Taro and many root crops have been part of the everyday diet until the introduction of rice and wheat. Over the years, the commercialization of agriculture and diminished local demand for taro has culminated in a gradual production decline. Taro Production areas were hit hard during the 2004 Tsunami and 2007 sea swells (Zahir, 2008). Consequently, the government has carried out two major projects to promote and rehabilitate taro production in this region. The most prominent of these is the work carried out under 'Regional Programme for Participatory and Integrated Agriculture, Forestry and Fisheries Development for Long-term Rehabilitation and Development in Tsunami-affected Areas' from 2008-2011.

Taro as vegetable: production, production area, uses etc.

The main production areas are in the islands of GDh Gan (uninhabited), GDh Vaadhoo, S Hithadhoo, Ga Konday and Gn. Fuvahmulah in the south Maldives (Table 1). Much of the production practices arose from these islands that also have strong cultural roots in farming. Additionally, production in irrigated areas has been observed in recent years in a few islands in the northern region; namely in Ha. Kelaa and HDh.Vaikaradhoo.

Land allocation of taro production areas has been observed from rent-free community plots to annual leased areas. On some farming islands such as Gn.Fuvahmulah, taro plots could be heritable, but those are managed by the island council. Agricultural land allocation is primarily a mandate of the respective island councils. Hence variations among islands are observed in leasing plots which depends on the available land area, history of farming, interested applicants and land-use plan.

Table 1. Major Taro Production Sites/Islands

Island	Total island/atoll area (ha)	No of taro Farmers	Taro cultivated area (ha)
G.Dh Gan (south)*	246	150	22
G.Dh Fiyori*	73	15	1
G.a Konday*	118	50	7
GDhVaadhoo*	198	100	3.7
Gn. Fuvahmulah*	491	approx.: 150	NA
Addu Atoll*	Approx: 500	approx.: 100	NA
HDhVaikaradhoo*	103	65	2.2

*Taro leaf blight disease reported, Reference: Grahame, 2008.

The production settings in the islands have been fine-tuned over many generations. Hence, not much has changed with current practices. Instead of raised beds, taro is cultivated in concave 1-meter-deep swamps and dug pits without border drainage systems. The pits vary from small separate patches of 5-6 meters diameter to larger fields up to quarter of a hectare. A farmer often manages more than one plot having an average farm size of about 400 – 1600 square meters (Grahame, 2008).

Usually, the pits are cultivated continuously often with varying aged plants in the same plot without fallow. This is also practiced to enable continuous harvest throughout the year from a single plot. This rainfed, wetland cultivation system has relied on monsoonal rain and year-round water management (Zahir, 2011).

Fertilizer management practices have been ad hoc and synthetic pesticides and fertilizers are not routinely used. Some farmers maintain fertility by adding the leaves of *Hibiscus tiliaceus*; however, this practice is not common (Grahame, 2008). On the other hand, ash seems to be used by all farmers, and is spread over the plots about 2 months after planting (when the plants have three leaves) at a rate of 25 kg on a plot of 100 x 50 ft (0.54 t/ha). The ash is from burning vegetation in the swamp. It is mixed with soil taken from under island vegetation (Grahame, 2008). Planting is carried out routinely after harvest on the same day. The spacing is about 30cm between plants (average 23 plants per square meter).

On average, a farmer produces 54 kg of taro per week. A significant portion of this is consumed at the household level. However, according to (Palomar, 2009) as much as 80 percent is processed or exported fresh to major local markets. Addu City and G.Dh.Thinadhoo are major hubs of consumption in the south. Nonetheless, much of the produce from the southern atolls are also transported to Male' central market on regular basis.

Demand for taro chips and fresh taro is well established in tourist resort islands as well as in local guest houses. Estimates by Palomar (2009), indicate that on average 20kg taro is sourced by resort islands per week. Taro as an ingredient is used in both staff and guest menus on regular basis. Additionally, souvenir shops and local stalls offer taro chips on sale.

Taro for Biodiversity and Sustainability

Nevertheless, taro as a crop still does not compete with major cash crops such as chili, watermelon, betel leaves, or coconuts. This is reflected in the local market prices where taro on average, fetch a lower price compared to these crops. Consequently, all the new entrants to the industry usually opt to grow other lucrative crops.

Traditionally, while men harvest taro from the swamp, women clean the corms, by removing the roots and leaves, and prepare the planting material – the leaf stalks with a small piece of the corm (Grahame, 2008). Yet, around 90% percent of taro farmers are senior citizens and older people near retirement age. Though in recent years women's participation has increased in all levels of agriculture, the number of youth and startup involvement in taro production is minimal.

In general, most southern islands with natural land depressions and wetlands are usually amongst the largest islands in the country. These islands often have rich biodiversity and tend to have a shallow soil profile towards the center of the island. Taro production also occupies the majority of the clay soil areas of these islands. Due to its long-term use in island ecosystems, taro is considered a part of the island vegetation for habitats that are conducive for its cultivation (Zahir, 2011). This is evident in the successful integration of cultivated varieties into the surrounding environment. Taro cultivated areas are rich in native and introduced tree species such as Pandanus (*Pandanus odoratissimus*), Funa (*Alexandrian laurel*), Kandhu (*Hernandia nymphaeifolia*), Uni (*Guettarda speciosa*) and Coconut (*Cocos nucifera*) (Zahir, 2011). They are also well suited for low light and forest garden production systems. Table 2 below shows the most common taro varieties cultivated in the country.

Table 2. Characteristics of four varieties commonly grown in the Maldives

	Olhuala (Swamp taro)	**Boduala (Big taro)**	**Raiala (Red taro)**	**Hudhuala (white taro)**
Leaf/plant size		Large	Tall	Large
Skin color	White	White	Red	Yellow
Skin thickness		Thick		
Flesh	White	White	White	White
Taste	Excellent	Good	Good	Good
Time to maturity	6 months	8 months	6/7 months	7 months
Growth rate	Slow	Slow	Fast	Fast
Corm shape	Cylindrical	Cylindrical	Cylindrical	Cylindrical
Storage	Good (7-10 days)	Good	Poor (3-4 days)	Moderate
Acridity			More than others	
Other				Cooks quickly

Source: (Grahame, 2008)

There have not been any major pest outbreaks of taro until the Taro Leaf Blight (TLB) disease in 2016. All known germplasm including the major four varieties are susceptible to TLB. It was first reported in 2016 and has spread within a few years to all major production areas. Taro cultivation has been heavily impacted by TLB unlike any disease incident in the past.

Nonetheless, the major cultivated varieties were tested negative for common virus diseases, namely *Taro bacilliform virus* (TaBV), *Dasheen mosaic virus* (DsMV), Taro reovirus (TaRV), *Colocasia bobone disease virus* (CBDV) and *Taro vein chlorosis virus* (TaVCV). Apart from TLB, some fungal issues of less economic importance caused by *Cladosporium spp* and *Johnstonia sp* or *Colletrotrichum spp* are reported by farmers occasionally. Whiteflies have been noted as the major insect pest that is mainly reported in the dry season. However, farmers rarely spray to control this pest.

Role of Taro in Nutrition security

Taro is considered a critical crop in striving towards self-sufficiency and nutritional security. According to statistics from Maldives Customs Services, 7.4 tonnes of Fresh Taro and related products were imported in 2019 with a combined CIF (Cost, Insurance and Freight) value of USD 50,000.

For these reasons, it has been part of many food security programs initiated by the government. Local variety enhancement practices, crop distribution activities and many awareness programs have been carried out to promote taro production and consumption over the years. Taro is included among major crops having significant importance for self-sufficiency. Among these crops also include banana, cassava, breadfruit and sweet potato. Moreover, taro encouraged as 'required cultivation' for all leased agriculture island holders under the Import Substitution Programme (MED, 2020). Similarly, in response to the Covid-19 crisis, the government has regulated to use of sparse land in islands for farming free of rent for three years. This was done in conjunction with the establishment of a state-owned enterprise - Agro-National Corporation (AgroNAT) which is also tasked to provide a platform for farmers to market and sell their produce (MED, 2020)

Taro is consumed in households as a substitute for wheat and rice. Hence, it is frequently included in weekly meal rosters. The level of consumption differs for islands where production is carried out. Taro has been popular due to the simplicity required in preparations. It is often consumed with fresh ingredients sourced from the islands such as chili, lime and coconut. With fish as a protein source, taro makes a good addition to a complex diet.

However, unlike in many countries, taro leaves are not consumed in the Maldives (Palomar, 2009). Earlier reports suggest the reason is the lack of awareness regarding the nutritional value of taro leaves. For the current generation, there is a lack of cultural backing or habits that prevents the integration of taro leaves in their daily diets. However, it is often supplied to resorts to prepare delicacies for tourists.

In recent years, with the advent of local tourism, demand for taro in inhabited islands has increased as an essential item to be reflected in traditional recipes. Major food products prepared from taro include boiled taro dishes, taro pie and taro chips.

Taro is also seen as high starchy food that often has to compete with other popular root crops such as sweet potato (*Ipomoea batatas*) and cassava (*Manihot esculenta*). It is also considered as a substitute food item for breadfruit (*Artocarpus altilis*).

Challenges

Flooding during the periods of intensive rain has been the most prominent issue for growers. Major flood incidents occur during the southwest monsoon (June, July and August) with few cases arising the rest of the year. It may take 10 days or more before the floodwater recedes and during that time, recently replanted taro and those up to 2-months old are destroyed (CDE, 2011). Additionally, leaves and corms of mature plants often get infected. Flood incidents are often exacerbated with seawater inundation due to associated rough seas in the southwest monsoon. This causes additional issues to the soil and the entire ecosystem (Zahir, 2011).

Most production areas are still confined to habitats that are considered either marshy, swampy or wetlands. This has restricted production in a fashion where prime lands are often reserved for high-value crops such as chili, brinjal, papaya and watermelon. For most taro growing areas, there are no long-term management plans. This disincentivizes active management for flood control or other collective land management operations (MHE, 2011). In areas with wetland management plans, cropping activities are often handicapped due to the strict regulations that favor low disturbance and indirect commercial activities. This is evident in plans prepared for large taro growing areas in Fuvahmulah and Addu atoll.

In recent years, the trade of imported live plants has increased significantly. Ornamental plants that are close relatives of taro such as *Xanthosoma* and *Caladium* are also heavily traded as well. Sometimes these species are grown together with taro in home gardens as ornamental plants. These activities increase the risk of new pests that might threaten the biodiversity of the taro-growing ecosystems. For instance, a survey records the heavy presence of invasive aquatic plant– Nile Cabbage (also known as Water Lettuce: *Pistia stratiotes*) in Fuvahmulah (MHE, 2011). Most growers and ornamental plant importers do not have the required knowledge to understand the potential negative impact to the ecosystem and taro producers from introducing new plant species.

Additionally, the taro production system has been adjusted for stock-less farming. However, for competitive commercial agriculture, animal manure may be required. Farmers find it challenging to source quality local manure. Farmers do not know to incorporate local poultry and goat rearing ventures with taro farming. Moreover, imported agriculture inputs such as soil amendments pose comparative losses to the ecosystem over the long run (MHE, 2011). Hence holistic yet sustainable taro production is challenged due to lack of local support services.

Similarly, basic infrastructure pertaining to essential support services is also lacking at the country level. This includes lack of crop testing and disease diagnostic facilities, storage and post-harvest management infrastructures, specialized transportation equipment, data collection and reporting mechanisms and taro processing facilities.

Similarly, processing and value addition activities of taro remain ad hoc and unimproved for much of history. Processing activities could be characterized as small-scale, household-level ventures. In some cases, neighboring communities band together under informal social contracts. The financial return is mostly marginal, and the social value is usually the main operator keeping these small-scale operations functioning. Most processors are often farmers who are involved in producing taro which limits the capacity for participation in value-addition business development. Additionally, producer groups have little or no knowledge on scaling up processing operations to match the current change in the market (MHE, 2011).

Prospects and Recommendations

There is a huge potential for diversifying taro products. Focus on the benefits of the whole taro plant as a beneficial product could improve consumption and market value of the crop. Special programs could be carried out introducing various taro recipes along with those made from taro leaves. In this respect, regional cultural knowledge, and culinary practices could be considered.

Country-level taro production targets could be set that reflect national agricultural plans. These targets should aim at reducing the taro imports and dependency on imported substitute food products such as rice and wheat. Similarly, local programs that support marketing taro to tourist resorts could be improved at the island level to promote business connections and increase production

Flood management infrastructure is to be developed in major growing areas in the south. International aid could be sought for this and objectives can be tied with improving local resource use efficiency and management. The plans for infrastructure are to be compatible with existing land-use or wetland management plans to reduce potential conflicts. In this respect, targeted community mobilization activities can be promoted among farmer communities to reduce the impact of flooding and other seasonal events.

Germplasm improvement programs could be carried out as major focused areas. This activity should target managing taro leaf blight and providing a mechanism for farmers to source quality cultivars. In conjunction, capacity development programs focusing on germplasm collection, cataloging and management is of huge importance.

Training and advisory programs can be developed to promote alternative production practices that can diversify taro production areas across the country. These programs could be developed in collaboration with international experts and regional institutions. This would reduce the dependency on wetlands and open opportunities for other islands to venture into large-scale taro production.

It is equally important to harness the potential for developing taro processing and value-addition activities. According to (Palomar, 2009) a micro-scale taro processing facility at the household level could be established for as low as 2340 USD. This would help standardize processing practices and improve the quality of various taro products. Value-chain activities can also be enhanced to reduce supply chain limitations.

Conclusion

The Maldives has a long history of taro cultivation. Many islands have elaborate cultures built around taro production. The system of cultivation has been heavily integrated into the lifestyle and natural ecosystems. Consequently, the production can be categorized as an organic or low input system. Moreover, taro consumption at the local level and tourist markets are stagnant owing to competition from imported food and lack of promotion and culinary development. Similarly, the potential value of taro is not realized due to the many challenges faced by farmers such as uniform production practices, aging population, diseases, high demand for land and lack of research and development. As such, many projects and programs could be built around, capacity building, infrastructure development, processing and value-addition activities and germplasm improvement. Immediate intervention is needed in controlling the incidence of TLB which has caused significant losses to the taro growers in the country.

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Chapter 7

Status of Taro (*Colocasia Esculenta L.*) in Nepal

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Abstract

Nepal is a landlocked country and is physically divided into three zones namely Terai (59-200 masl), mid-hills (200-1500 masl), high hills (1500-2500 masl). The zone(s) which lie above 2500 to 8000 meters are not suitable for cultivation. With the diverse agro-ecological condition, about 200 plant species are being used as vegetables, most of the niches neglected or underutilized including taro. Taro is mostly cultivated in upland areas of Nepal although some wild types of taros are grown in marshy lands whose leaves are consumed as green vegetables. This crop has been considered an underutilized crop in Nepal because this has not got much attention for cultivation by farmers and also government agricultural programs have very little or no emphasis on its promotion. Taro (*Colocasia esculenta*) is well adapted to marginal land and drought conditions; it is mainly cultivated in upland areas of almost all households. In Nepal, it is uniquely adapted to home garden conditions and provided support for food security. Because of its easy cultivation, propagation and longer storage life, it has become more common vegetable for every household. Some landraces have a high level of calcium oxalate, but with the indigenous knowledge farmer can distinguish cultivars. There are some varieties whose petioles are eaten as green salads (?) and fresh pickles. Different varieties have been cultivated throughout the country. Diversities are found across the country. The use of taro as a vegetable varies according to types, location and ethnic groups. Although it has higher productivity (20-30 mt/ha) as compared to other cereal crops, production is less because of lower priority as crop. Higher nutritional values, availability of fallow and uncultivated land, opening of markets nearby rural areas are some prospects of taro production in Nepal. Priority should be given for research and development of taro by utilization of its existing diversity as well as import of high yielding variety from neighboring country through regional networking is important for food and nutritional security of people in the country.

Introduction

Nepal is a landlocked country surrounded by India in the East, South, and West and China in the North with a total area of 147517 square kilometers. The country is physically divided into three zones namely Terai (59-200 masl), mid-hills (200-1500 masl), high hills (1500-2500 masl) and the zone which lies above 2500 to 8000 meters are not suitable for cultivation. Valleys, river basins and some special niche areas in mid and high hills are suitable for many special types of crops cultivation. The country's total cultivable land is 28.75% where only 21% of the land is cultivated. With the diverse agro-ecological condition, significantly higher numbers of plants are grown and consumed as vegetables. Almost 200 plant species are being used as vegetables, most of them are neglected or underutilized including taro. Taro is cultivated in upland areas of Nepal although some marshy lands have some wild types of taros whose leaves are consumed as vegetables. This crop has been considered in Nepal as an underutilized crop because this has not got much attention for cultivation by farmers and also government agricultural programs have very little or no emphasis on its promotion as a vegetable as well as nutrition point of view. Promotion, utilization and commercialization of such underutilized crops help to combat the nation's food and nutrition security particularly in remote and hilly areas of Nepal (ABTRACTO, 2005). Taro (*Colocasia esculenta*) is an important vegetable crop in the hills of Nepal (Pandey et al., 1998). Since it is well adapted to marginal land and drought conditions, it is cultivated in upland areas of almost all households. In Nepal, it is uniquely adapted to home garden conditions and provided support for food security. Because of its easy cultivation, propagation and longer storage life, it has become more common vegetable for every household. Some landraces have a high level of calcium oxalate, but with the indigenous knowledge farmer can distinguish cultivars. There are some varieties whose petioles are eaten as green salads and fresh pickles.

Area and Production of Taro in Nepal

Taro is found to be grown here and there in Nepal as wild and cultivated forms. It is popularly grown in the hills and consumed by the hill habitats as a vegetable. It is a common component of home gardens and is grown in all most all households in Nepal and consumed by the growers only. In 2018/19 Taro was grown in 5,214 (ha) of land with a total production of 60,709 (mt). In the same growing season yield of taro was 11.64 (mt/ha) (SINA, 2020) which was lower than some other SAARC Countries.

Province-wise area, production, and yield of taro in 2016/17 are presented in Figure 1. Among the provinces the highest area of land was under taro cultivation in Gandaki province followed by Sudurpashchim, kamali and Province 2. A similar trend was followed by the total production which was also highest in the Gandaki province followed by Sudurpashchim, kamali and Province 2.

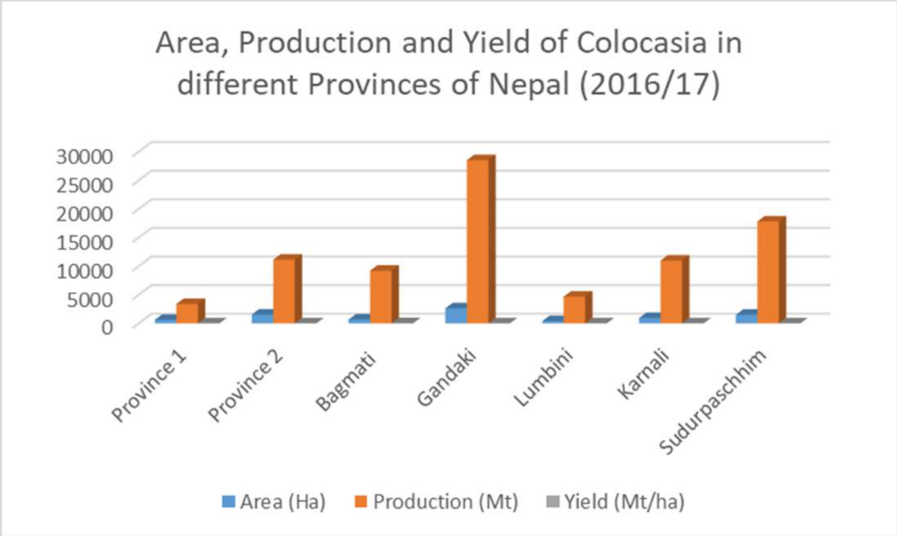

Figure 1. Coverage of Colocasia among Underutilized Root and Tuber crops in Nepal (Potato and sweet potato not included) in 2016/17

Utilization of taro in Nepal

Colocasia has been utilized in Nepal as vegetable for long time. Some ethnic groups still seem to collect the leaves of wild taro grown in marshy land for vegetable purposes. The importance of taro cultivation in Nepal has been increasing in recent years. Traditionally it has been cultivated in abandoned land nearby houses where other crops do not perform well. The consumption of taro in Nepal is confined to May-July (for fresh leaves as vegetables) and February-April (corms and cormels as vegetables). According to relative use-value, farmers use local names annexing either *karkalo* (aerial part) or *pidalu* (underground part). The aerial part (leaves, petioles and inflorescence) is used as fresh vegetables. Some landraces can be eaten as salads and pickles. Different ethnic groups have their way of preparing cuisine from taro and there are special occasions and festivals when the products of taro are relish. Farmers use taro in different forms and most of its products are prepared in such a way that they can be stored longer and meet the need of off-season scarcity. Use and preparation of different forms of food/vegetable items depend upon the type of variety, location and their use either as sole or mixed with different other food and vegetable vary with ethnic groups. Young and central leaves of taro are freshly cooked with different spices and condiments for the preparation of *Gava* (Tender shoot) which is a very popular vegetable recipe almost all over in Nepal. Most popular items prepared from taro for later use are *leaves powder, sukuti tyandra, masyaura* and *corm powder. Leaves powder is* prepared by selecting tender leaves which are steamed and then sun-dried and crushed in powder. This powder is used with other vegetables and cooked. Likewise, leaf stalks are cut into small longitudinal pieces and sun-dried to prepare su*kuti tyandra* and kept for later use. These are cut into small pieces and mixed with other vegetables before cooking in lean period. While preparing *masyaura,* leaves stalked are cut into small pieces and mixed with powder of legumes (black gram, cowpea etc) and beaten until these are well mixed. Then 10-20 gram pieces are made and sun-dried and kept for later use.

Diversity of Taro in Nepal

Nepal has very diverse agroecological conditions where different types of crops are cultivated during the same season. Crops right from tropical to temperate are being cultivated in Nepal. Although taro is originally a tropical vegetable crop, it has been cultivated from 100 masl to 2500 masl with the use of different varieties/cultivars. There are different types of taro like petiole eating type, single corm type, multi corm type, and many cormels types are found across the country (Pandey, 1995). Farmers in association with their cooperatives, NGOs and government agencies occasionally used to organize diverse fair of crops. Various types of taros are displayed in the fair which is grown near that agroecological domain (Pandey et al., 1998). Generally, high altitude (>2000 masl) grown taro have very small types of corms and cormels and leaves of this taro are usually consumed during the rainy season. Small corms of different shapes and sizes are found which are left in situ for next season crops (HRS, 2016). The majority of taros are cultivated in mid-hills throughout the country where different varieties of taro are found. Horticulture Research Station, Malepatan, Pokhara (2015) has collected different types of taro from farmers' fields and has just initiated research on it. Similarly, Root and Tuber Crop Development Center, Sindhuli under the Ministry of Land Management, Agriculture and Cooperative of Province No. 1e government has initiated the collection and further development-related program of Taro. Some of the collections with their characters are presented in Table 1 below.

Table 1. List of the landraces of *Colocasia* maintained at the Horticulture Research Station, Malepatan, Pokhara, Nepal.

Sl. No	Landraces	Major corm /cormel characteristics
1	Hatti Paun (Elephant foot)	Brown color, Multi-faced (Many Eyes bud in a corm), Round shaped corm, fewer cormel numbers.
2	Bhainsi Khutte (Buffalo foot)	Flattish round brown corm, medium number of cormlets, and medium-sized com.
3	Bermeli Pindalu	Red and round-shaped medium-sized corm, cormlet Number medium
4	Chhattare Pidalu	Brown medium size corm, more corms let number with long shaped
5	Dudhe Pidalu	Round and brown corm, corm let number more
6	Thado Mukhe (Errecta)	Long shaped corm, number of cormlets, brown in color
7	Khujure	Oval type brown corm, corm let number more
8	Rato Bhale (Red cock)	Red in color, small size corm, corm let number more and long in shape
9	Sat Mukhe Pidalu (Seven faced)	Multi faced (Many eyed buds in a corm), less corm lets, corm Shape flattish round
10	Rato Mukhe (Red faced)	Red and round-shaped corm, corm let number medium
11	Pancha Mukhe Pidalu (five faced)	Flattish round brown corm, no corm lets
12	Lahure Pidalu	More corm let number, small size corm, brown-colored round corm
13	Gante Pidalu	Round and medium-sized corm, higher number of cormlets,
14	Chhaure Pidalu	Brown and small corm, maximum numbers of cormlets
15	Khujure Rato Pidalu	Medium Brown oval shape corm, corm let number more
16	Thaune Pidalu	Big oval-shaped corm, fewer number of cormlets, brown in color

Table 2. List of Taro maintained at field gene bank of HRS, Malepatan and their corm and cormels characters

SN	Name of landraces	Corm diameter (cm)	Individual corm weight (g)	Number of cormels	Individual cormel weight (g)	Corm color
1	Bhainsi Khutte	16.1	1300	2.2	15.2	Brown
2	Bermeli	8.1	385	8.4	45.2	Red
3	Chhattare	8.3	574	8.6	59.8	Brown
4	Hattipaun	17.2	1420	1.2	14.3	Brown
5	Thado Mukhe	7.2	520	7.6	58.5	Brown
6	Khujure	9.0	576	3.4	43.8	Brown
7	Rato Bhale	10.8	545	2.4	80.5	Red
8	Sat Mukhe	11.9	770	2.6	59.2	Brown
9	Pancha Mukhe	15.1	1230	3	441	Brown
10	Thaune	8.1	346	12.6	25.1	Brown
11	Lahure	9.9	920	12.6	35.8	Brown
12	Gante	9.6	493	11	27.4	Brown
13	Chhaure	10	696	10.2	57.4	Brown
14	Khujure Rato	9.8	598	6.8	59.2	Red

(Source: HRS, Malepatan, Pokhara, 2017)

Taro has as many diversities as compared to other vegetables cultivated in different locations. In practice, farmers are cultivating as many as 2-3 varieties of a single vegetable crop in a specific area but have more than 5-6 types of taros. Most of the Taro has been grown in marginal land without/nominal use of agricultural inputs. Productivity has been found as high as 30 mt/ha. No chemicals have been used to manage the insect pest and diseases (occasionally local materials are used to escape). Cultivar for higher yield and disease and insect tolerance can be selected for commercial production from the resource.

Role of Taro in food and nutritional security

Majority of the population is dependent on rice-maize and wheat-based feeding habits. Larger area of the country lies in mid and high hills where amount of rice and wheat production is significantly low. With the ease of road access, feeding habit of hill people is shifting to rice and other products which have led to poor nutritional security in remote areas. Majority of population has limited/marginal land to cultivate cereals to meet their food requirement hence has to depend on purchase. Such land can be brought in cultivation with the crop which has higher productivity that can substitute the food requirement. The productivity of Taro is much higher (15-20 mt) as compared to cereals (3-6 mt) with minimum inputs used and Taro corms have higher starch content (70-80%) and can contribute to food supplements instead of cereals. Rural people used to consume corms and cormels not only as vegetables but also as staple food during harvesting time (since quantity is less, it lasts for only a few days). Not only energy food, but taro leaves are also rich sources of iron and other minerals (Heiser, 1990), so the increased consumption will help to fulfill the nutritional requirement of rural and hilly people at cheaper cost. Awareness of the nutritional value of taro leaves, corms and their products and taste has created demand in urban areas, so there are chances of earning money.

Challenges and prospects of Taro cultivation in Nepal

Challenges

Planting Material Management: Planting materials used by farmers for taro cultivation is generally of poor quality because farmers usually plant the materials which are left over after consumption. Since it is bulk in nature, needs large quantity of planting materials, its cultivation is confined to lesser areas. Taro in-country is propagated vegetatively. Clonal planting materials from generation to generation has led to quality deterioration.

Production: Production of Taro in Nepal has not yet been commercialized and production is mainly ad-hoc and based on traditional knowledge and confined mostly in marginal lands without irrigation that's why production area, productivity, and total production is stagnant for a long.

Harvesting and Post-Harvest Handling: Harvesting and post-harvest loss are as high as 5 to 20%. Farmers have the problem of storing the corms for a longer period. Since, harvested in late winter, with the rise in temperature and humidity during summer and rainy season, there are higher postharvest losses.

Marketing: Collection centers and storage facilities are very limited. Since it is bulky, it requires a higher cost for transportation, processing and storage.

Prospects of taro cultivation in Nepal

Input and Planting Material Management: Taro has been cultivated with minimum inputs and still is getting good crop yield. Since it is vegetatively propagated, varietal deterioration is very less if little care is given. Taro is highly responsive to organic manure so production can be increased significantly using local materials like compost and it is less affected by diseases and pest attacks in Mid hill conditions of Nepal.

Production: Production of taro is possible in marginal lands without irrigation (with mulching and compost). Farmers are producing taro without chemical fertilizers and pesticides so, organic taro production is possible in the country.

Harvesting and Post-Harvest Handling: Taro corms can be harvested with fewer manual labor. It can be stored in the field or in normal condition for a longer period as compared to other fresh vegetables. Big departmental stores and food marts are opening nearby rural areas so there is a big opportunity to sell the produce from these outlets.

Processing and Marketing: The establishment of small-scale processing units in production sites will provide not only the opportunities for employment to rural people but also diversified the products from different parts of taro which will supply food and nutrition to the consumers.

Recommendation

1. **Short term**

- Establish a separate research division on root and tuber crops
- Identify and develop new varieties and production technology and also distribute quality planting materials
- Provide technical services in the command areas in collaboration and coordination with province-level and local level extension offices
- Develop GoN farm as a practical training resource center for field-level technicians, cooperatives/farmers to transfer modern production and post-harvest technology.
- Campaign utilization of fallow (*Banjho Jagga*), marginal land, small farmers, and awareness creation about its value

2. **Medium-term**

- Develop *expert's team consisting of* Breeder, Plant Protection Specialist, Soil and Crop Nutrition Specialist, Post-harvest and Marketing Specialist, etc.
- Develop suitable varieties of Taro crops for processing industries and Explore the possibility of industrial use/processing through the private sector.

3. **Long term**

- Develop well-equipped research centers and export production zones
- Develop farmers resource centers to produce high-quality planting materials
- Develop and manage Taro crop horticulture technicians at ward level who can provide embedded service to the clients
- All research, teaching, and development services are linked by one chain of command from Central, Province, and Local level government through one window command of Research Coordination Committee.
- Study external demands for Taro product, flour, and powder of taro, encourage private sectors for opening industries along with the commercialization of the produces.

Conclusions

Considering the wider scope of Taro, several potentialities are there in food & nutritional security obtained in south Asian countries through mutual benefit and regional cooperation along with exploration, collection, and utilization of available biodiversity resources.

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Chapter 8

Status of Taro in Pakistan

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Abstract

Taro (*Colocasia esculenta*) is widely cultivated in the tropical and subtropical regions of Southeast Asia, East Africa, the Caribbean, and Southeast America. Taro is commonly called arvi or arbi in Pakistan and is cultivated as a summer crop. Corms of taro are used as a vegetable, occasionally young leaves are also cooked. The leaves are a source of vitamins A, B, and C. Taro is considered an aphrodisiac, tonic, and reputed to have a curative effect on coughs and diarrhea. The status of taro as a vegetable in Pakistan is reviewed.

Introduction

Genus *Colocasia*in the monocot family Araceae comprises 11 species native to Assam, Bangladesh, Borneo, China South-Central, China Southeast, East Himalaya, India, Laos, Malaya, Myanmar, Nepal, Nicobar Is., Sumatera, Taiwan, Thailand, Tibet, and Vietnam. *Colocasia* is represented by one cultivated species in Pakistan – *Colocasia esculenta* (Linn.) Scott (Figure 1- 5).

Taro or arum is the common name of *Colocasia esculenta* which is a tropical perennial plant. It is widely distributed in entire Southeast Asia, East Africa, the Caribbean and Southeast America. It has starchy corms and edible leaves. In Pakistan, taro is commonly known as arvi, arbi and kachaloo and it is cultivated as a summer crop. Corms of taro are used as a vegetable in Pakistan. A recent study by Ahmed et al. (2020) showed that as an ancient clonal root and leaf crop, taro (*Colocasia esculenta*) is highly polymorphic with uncertain genetic and geographic origins. By exploring chloroplast DNA diversity in cultivated and wild taros, and closely related wild taxa, Ahmed et al. (2020) found cultivated taro to be polyphyletic, with tropical and temperate clades that appear to originate in Southeast Asia sensu lato. A third clade was found exclusively in wild populations from Southeast Asia to Australia and Papua New Guinea.

Alocasi amacrorhiza (Linn.) G. Don is erroneously mentioned as 'arvi', 'arbi' in Flora of Pakistan (Nasir, 1978), which in fact is elephant ear taro – an ornamental plant, while vernacular name given for *Colocasia esculenta* in Flora of Pakistan (Nasir, 1978) is 'kachalu'. Kachalu in fact are mother corms of *Colocasia esculenta*, while new corms are sold as a popular vegetable called 'arvi' or 'arbi'. Boiled kacahlu is often sold by roadside vendors in Khyber Pakhtunkhwa which is sprinkled with lemon and garnished with red chili. Young leaves are also occasionally cooked as a vegetable both in urban and rural households. Leaves are coated with a paste of chickpea flour, rolled and cooked by steaming, or are fried to make 'pakoras'. According to Flora of Pakistan (Nasir, 1978), it is cultivated for its starchy tuberous corms, which when boiled lose their poisonous nature and can be eaten.

Production Area and Uses of Taro

Since mostly cultivated plants are harvested before flowering, fruiting, and seed maturity, taro is mainly propagated vegetatively for which cormels, corms, and stolons are used as seed (Nyman & Arditti, 1985; Ahmed, 2014; Matthews, 1990). The successive selection of plants in sub-tropical to temperate areas with seasonal cropping systems like Pakistan occurs without seed setting (Ahmed, 2014). A field study was conducted by Ahmad et al. (2018) at Dargai in Malakand district to evaluate the response of *Colocasia esculenta* to different levels of nitrogen viz 0, 60, 90, 120, and 150 kg N ha^{-1} in the form of urea along with a uniform basal dose of 90 kg P_2O_5 ha^{-1} as Triple Super Phosphate. The study showed that 60 kg N ha^{-1} was appropriate in terms of maximum relative yield and increase over control for *Colocasia esculenta* under the prevailing soil and climatic conditions. Taro is mostly grown in the Khyber Pakhtunkhwa and Punjab provinces of Pakistan. It is also grown in small areas in Sindh province. The area under taro in Punjab, Sindh, and Khyber Pakhtunkhwa and its production during 2014-2019 are given in Tables 1 & 2.

Table 1. Area (ha) under taro production in Pakistan during last five years

	2014-15	**2015-16**	**2016-17**	**2017-18**	**2018-19**
Pakistan	**2757**	**2514**	**2431**	**2912**	**2388**
Punjab	1153	938	939	1267	1007
Sindh	231	231	234	207	105
Khyber Pakhtunkhwa	1373	1345	1258	1438	1276

Source: GoP, 2020

Table 2. Production (tons) of taro in Pakistan during last five years

	2014-15	2015-16	2016-17	2017-18	2018-19
Pakistan	30575	29448	24823	29136	24281
Punjab	13210	10618	10561	14520	11351
Sindh	895	896	903	799	406
Khyber Pakhtunkhwa	16470	17934	13359	13817	12524

Source: GoP, 2020

Taro for Biodiversity and Sustainability

The study of crop biodiversity is important for conservation and sustainable utilization. During a study on isozyme variation in 1,417 cultivars and wild forms of taro collected in Asia and Oceania, it was reported that there is signification variation in taro in terms of morphological characters such as leaves, tubers and flowers, and chemical constituents (Lebot and Aradhya, 1991 cited in Abdullah, 2016). The only detailed investigation on the genetic/morphological diversity of taro in Pakistan is that of Abdullah (2016). During this study, 18 taro plant samples were collected from three provinces of Pakistan including Khyber Pakhtoon Khwa (KPK), Sindh, and Punjab. Cormels of all samples were planted in Nowshera and Gujar Khan areas. Morphological and molecular analyses of each sample were evaluated to check genetic diversity. The study showed significant variation for morphological characters in taro from different areas of Pakistan. Morphological characters including plant height, leaf color, leaf veins color, leaf length, leaf width, petiole color, petiole height, and petiole sheathed edge area showed variation. A 592bp fragment of chloroplast amplified using ACEP05 primer was used in this study which exhibited the presence of genetically diverse taro in Pakistan which belongs to the Himalayan superclade (Abdullah, 2016).

Role of Taro in Nutrition Security

An estimated 400 million people in the tropics and subtropics use taro in their diet as a staple food (Abdullah, 2016). The corms of taro are relatively low in protein and fat but are a good source of starch, fiber, and ash. Taro is also a good source of thiamine, riboflavin, iron, phosphorus, zinc, vitamin B6, vitamin C, niacin, potassium, copper, and manganese (Rashmi et al., 2018). Considering the nutritional importance of the crop, it can be considered an underutilized crop in Pakistan. Corms are made into curries and are often cooked in combination with meat. The leaves are also edible and a source of vitamins A, B, and C (Nasir, 1978). The juice from the corm and the petioles is medicinal, being used as a stimulant, rubefacient, and as a styptic (Nasir, 1978). Taro is considered an aphrodisiac, tonic, and reputed to have a curative effect on coughs and diarrhea.

Challenges and Prospects of Taro in Pakistan

Taro has been a neglected crop in Pakistan, despite its common use as a vegetable, there has not been documented record of genetic diversity in taro apart from the recent study by Abdulla (2016). Standard descriptors to identify different varieties of taro are not available with the Federal Seed Certification and Registration Department, the Government agency with a mandate to record new varieties of crops (Abdullah, 2016).

Recommendations

Genetic diversity of taro is important for crop improvement and promotes its cultivation and use. Genetic diversity of taro germplasm in Pakistan should be studied using morphological, biochemical, and molecular markers. Breeding programs should be initiated to develop high-yielding taro varieties with better quality. Exchange of taro genetic resources among SAARC countries should be promoted for their utilization in crop improvement. Exploration, conservation, evaluation, and utilization of genetic diversity in *Colocasia esculenta* germplasm can play a great role in food and nutritional security.

Conclusion

Taro (*Colocasia esculenta*) is an important tuber crop that is a widely cultivated vegetable; as a source of starch and other nutrients. But it is an underutilized crop in many countries of the world including Pakistan. Existing germplasm of taro in Pakistan should be conserved and utilized for crop improvement. Exchange of germplasm among SAARC countries can also play a significant role in crop improvement and food security in South Asia.

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Fig. 1. Different parts of *Colocasia esculenta*

Chapter 9

Status of underutilized Taro (Colocasia esculenta) in Sri Lanka

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Abstract

Taro or edible aroids (*Colocasia esculenta* and *Xanthosoma spp*.) are one of the commonly consumed local root and tuber crops in Sri Lanka. Though it is popularly grown as vegetable, but it is still an underutilized crop in Sri Lanka. At present limited number of research works have been carried out on edible aroids compared to other root crops such as potato, cassava, and sweet potato. Sri Lanka is rich in the natural diversity of taro and depending on the time required to corm formation after planting several local accessions were identified in different age groups, such as two months' group and three months' group. It is not a seasonal crop in Sri Lanka and can be grown throughout the year. Recently few varieties were developed from the local germplasm and at the same time attempt has been taken to develop process products such as taro chips. For promoting Taro in Sri Lanka, it is necessary to give proper emphasis on research works on taro.

Introduction

Sri Lanka is an island with a land extent of 65,525 sq km and is located between 50 54′ and 90 52′ north latitude of the equation and 790 39′ and 810 53′east longitudes. The Island has a maximum length of about 435 km and its maximum width is nearly 225 km.

The climatic pattern of the country is determined by the monsoonal wind patterns in the surrounding oceans. Rainfall is monsoonal, convectional, and depressional and 55% of the rainfall comes from the monsoons to the country. The mean annual rainfall ranges between 900 to 6,000 mm. The country is divided into three broad climatic zones as wet zone, dry zone, and intermediate zone based on the rainfall and its distribution (Fig. 1).

Figure 1. Climatic Zone in Sri Lanka

The mountains and the southwestern part of the country, known as the "wet zone", received an annual rainfall of 2,500 mm. Most of the southeast, east, and northern parts of the country comprise the "dry zone", which receives between 1,200 and 1,900 mm of rain annually covering two-thirds of the country. Much of the rain in these areas falls from October to January; during the rest of the year, there is very little precipitation.

The rainfall distribution in the country shows a bi-modal pattern with two growing seasons; a relatively wet season "Maha", from October to February, and a comparatively dry season "Yala", from March to September (Fig. 2).

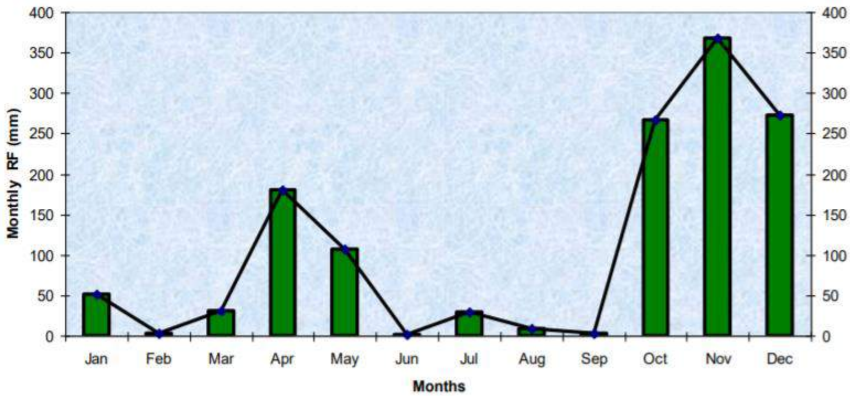

Figure 2. Bimodal Rainfall Pattern in Sri Lanka

Reddish-brown earth is the most widespread soil group in the country occupying the largest area (1.6 million ha) compared to all other soils and also mainly confined to the dry zone in the country. Agricultural land area in Sri Lanka is 27,400 sq. km and it is about 43.7 % of the total land extent and 32.9% of the land is reserved forest area. In Sri Lanka, home gardens cover more than 13% of the total land extent (Yapa, 2018). Pushpakumara et al. (2012) highlighted that home gardens are one effective way of ensuring access to a healthy diet that contains adequate macro and micronutrients to produce diverse kinds of foods in farming systems. This further revealed that Sri Lankan home gardens are dominated by food use species demonstrating their contribution to food plant diversity. Especially in wet zone home gardens or Kandyan home gardens provides a niche for Colocasia esculenta which is cultivated for home consumption as well as a medicinal plant.

General information of root and tuber crops production in Sri Lanka

Local root and tuber crops are indeed an alternative for achieving the food security of the nation. Root and tuber crops, which are underground bulky perishables and vegetatively propagated, can be used as a main meal, side dish, and as well as in preparing snacks and crackers. The factors such as high adaptability for the different climates in a wide range, availability of at least one or more variety throughout the year, easy management, minimum pest attacks, less input and attention required, and ability to cultivate in marginal lands confirm the greater potential of cultivating local root and tuber crops towards the food security (Alwis et al., 2017).

The major and more commonly consumed local root and tuber crops in Sri Lanka are Cassava (Manihot esculenta), sweet potato (Ipomoea batatas), yams (*Dioscorea spp.),* and edible aroids (*Colocasia esculenta* and *Xanthosoma spp*.). Due to the wide range of agro-ecological adaptation, local tuber crops can be grown throughout the year as well as throughout the country. Today, local root and tuber crops consumption and cultivation however have been ignored and most of these crops are facing a threat of extinction in Sri Lanka. There is a large number of studies were carried out on potato, cassava, and sweet potato, however, there is only limited number of research work carried out on yams and edible aroids at present (Sangakkara and Frossard, 2014).

Leading root and tuber crops cultivation in Sri Lanka

Major root and tuber crops cultivated in Sri Lanka are cassava, potato, and sweet potato. The total extent of cultivation of the above-mentioned crops in 2018 was 31,684 ha with a total production of 455,328 tons (Agstat, 2018).

Table 1. Extent, production, and productivity of leading root and tuber crops in Sri Lanka in 2018

Crop	Extent (ha)	Production (t)	Productivity (t/ha)
Cassava	22,361	323,108	14.5
Potato	5,174	88,897	17.2
Sweet Potato	4,099	43,323	10.6

Source: Department of Agriculture Statistics, 2018

Present status of Taro (Colocasia esculenta) in Sri Lanka

Taro is important in food security as it has a wide range of ecological adaptability, and it is a good source of starch given within short period. In Sri Lanka, most popular aroid is *Xanthosoma spp* call as "Kiri Ala" which is cultivated commonly on commercial level and in home gardens and the product is marketed in the local and foreign market. However, at present taro is not a commercially cultivated crop in Sri Lanka., it is only cultivated in the low country and mid-country wet zone home gardens as a traditional crop, but not on large scale. As Colocasia esculenta is a non-seasonal crop, it can be cultivated throughout the year under irrigation conditions. Department of Agriculture has released One Xanthosoma variety ("Isuru") and two Colocasia esculenta varieties, namely Gaja" and "Dimuthu". There are different accessions in the country with different age groups, such as two months group and three months group. There are different local accessions were identified in Sri Lanka. Such as:

Dehi ala	Wali ala	Kurudu ala	Gahala/ Kola
Sevel ala	Demas ala	Tadala	wel ala (Wild type)

They are tasty and rich in nutrients and there is a high demand.

Nutritional and Therapeutic Value

The corms have high content of starch and protein (Table 2). The *Colocasia* starch contains amylase and the mucilage contains D-galactose, L-arabinose, and uranic acid. The whole plant is a source of vitamin B.

Table 2. Nutritional and therapeutic values in tuber and leaves of *Colocasia esculenta*)

Components	Tuber (in 100 g)	Leaves (in 100 g)
Moisture	73 g	93 g
Energy	102 kcal	24 kcal
Protein	1.8 g	0.5 g
Fat	0.1 g	0.2 g
Carbohydrates	23 g	6 g
Calcium	51 mg	49 mg
Phosphorus	88 mg	25 mg
Iron	1.2 mg	0.9 mg
Thiamin	0.1 mg	0.02 mg
Vitamin C	8 mg	13 mg
Niacin	0.8 mg	0.4 mg
Riboflavin	0.03 mg	0.04 mg

Source: (FAO, 1972 and 1986)

Recommended management practices in Sri Lanka

Fertile soil with water retention capacity is ideal. Good drainage is required. A temperature of 21 – 27 ^{0}C and well-distributed rainfall of 1000 – 1500 mm are good for taro. Mostly production occurs at altitudes below 1000 m.

- Areas of cultivation: Low country and mid-country wet zone of Sri Lanka
- Planting season: Almost throughout the year except during the dry months
- Land preparation: The land should be worked to a depth of 20- 25 cm
- Planting material: Consists of either the crowns or tubers
- Planting spacing: Planting is usually done in individual planting holes. Tubers are buried 7.5- 10 cm at 1 m x 1.5 m spacing
- Fertilization: Respond well to manuring. Heavy application of cattle manure or compost at planting could double the tuber yield. There is no fertilizer recommendation given by the Department of Agriculture
- Harvesting: Time to harvesting depends on the variety, the crop may be lifted from 3 months onwards
- Harvest: Tubers should be lifted carefully digging the whole plant out without damaging the tubers. Fresh tuber yield of 15 – 20 t/ha can be obtained from the varieties in Sri Lanka

Colocasia esculenta varieties and accessions in Sri Lanka

Figure 3. Dehi Ala

1."Dehi Ala"

Variety name "Gaja" Plant height is about 50-65 cm. Purple mixed green color can be observed in the place where petiole fixes to the leaf. Purple dot is visible on top of the leaf. 4-5 primary corms can be observed around the mother comes then 12-15 corms comes from them at about 1 ½ - 2 months. One corm is weighed about 40-50 g. Lemon shape corms are covered with brown color outer skin. Harvesting can be done 5- 6 months after planting (Fig 3).

Figure 4. Weli Ala

2 "Wali Ala"

Variety name- "Dimuthu" Plant height is about 25-35 cm. Leaf-blade and the petiole are green in color. 8-10 Primary corms can be observed at 30-35 days. 20-25 secondary corms can be harvested as clusters at 3 ½ - 4 months after planting (Fig. 4).

Figure 5. Selev Ala

3. "Sevel Ala"

Plant height is about 85-90 cm. Plants are bigger than the above two varieties. Leave are purplish-green in color and the petiole is purple in color. One corm is about 40-50g in weight. When cut the corms, ooze comes out (Fig. 5)

Other accessions

i) "Thadala"

Light green in color. Roots occur on the surface of the earth and produce corms. Whole plant can be utilized. In Ayurvedic medicine this variety is used for treatments in joint pains (Fig. 6).

Figure 6. Thadala Ala

Uses of Taro in Sri Lanka

- Tubers are boiled and eaten. Other than that, tubers are boiled and used to prepare a curry
- Leaves are eaten as a green vegetable or prepared that as curry as well

Taro Recipe

Taro tuber curry/ Kiri ala curry

1. Ingredients (for 3-4 servings)
2. 300g Taro tuber,
3. ½ of medium-sized onion sliced,
4. 2-3 green chili sliced,
5. 1 teaspoon raw curry powder,
6. ½ teaspoon turmeric powder,
7. 1/4 teaspoon Fenugreek seeds,
8. Piece of Cinnamon,
9. Rampe & curry leaves,
10. Salt as per taste,
11. 1 cup thin coconut milk,
12. ½ cup thick coconut milk

Preparation Method

Step 1: Prepare taro for cooking

Peel the skin. Wash thoroughly. Cut tubers into small size pieces.

Step 2: Prepare the curry in a pan, place tuber pieces. Add all ingredients above other than thick coconut milk. Mix well and cook until taro is boiled well. Finally, add thick coconut milk and mix well. Simmer few minutes until coconut milk starts boiling. At this point check salt and adjust if necessary.

Switch off the flame and keep the curry on the stove. The hotness of the stove is good enough to thicken the curry. It is ready to serve with plain rice.

In Ayurvadic medicine

- The pressed juice of petioles is used to arrest arterial hemorrhage
- Use for earache and otorrhea
- As an external stimulant and rubefacient
- Antidote for strings of wasps and insects
- Ash of the tuber mixed with honey is used for aphthae in the mouth (Jayaweera, 1981)

Value-added products

In 2019 Sri Lankan company introduced an innovative product to local people as "Taro Chips"

Figure 7. Taro chips value-added product in Sri Lanka

Other uses

- Leaves are used as wrapping materials

The potential of cultivation of Colocasia esculenta is very high in Sri Lanka as Taro is grown in wide ecological conditions in which other crops may find in difficult or adverse such as waterlogged, saline soil, or shady conditions. In Sri Lanka, Colocasia esculenta is cultivated as a crop in around 25 acres of land throughout the country.

Present problems in the cultivation of taro in Sri Lanka

1. Lack of information and knowledge regarding the crop
2. Unavailability of planting materials /no proper way to find planting materials
3. No proper local and foreign market channel for the farmer to sell their product
4. Less awareness about the crop among the new generation
5. Less strategic options for an increase in Taro production.
6. Less awareness, consumer education, and on its nutritional and health benefits

Potentials of Taro (Colocasia esculenta) in Rural Development in Sri Lanka

1. Colocasia esculenta is not a seasonal crop, so the potential of cultivation throughout the year increase farmers' income throughout the year without fluctuation. Taro can be cultivated two times per year due to the shortage character and in Sri Lanka, there are main two growing seasons called Yala and Maha. Therefore, taro can be cultivated targeting these two seasons, which ultimately increases farmers income.
2. Local and Foreign market demand is high for the *Colocasia esculenta*. The taro industry provides significant employment to a large number of people, mostly in rural areas. Where taro exportation occurs, then the facilities for cleaning, sorting, packing, and shipping will provide employment. Therefore, the taro provides additional avenues for poverty alleviation and employment generation in rural areas.
3. While a lot of taro is produced and consumed on a subsistence basis, quite a little amount is produced as a cash crop. Also, surpluses from subsistence production can manage to get income by marketing. Therefore, it is significant as a provider of food security and act as a cash crop and earner of foreign exchange, thereby playing a role in poverty alleviation and earning foreign exchange within short period. As Xanthosoma (Tania) exportation, taro also has a good potential for cultivation and exportation.
4. In Sri Lanka there are about 163,562 Ac of fallow paddy lands. Therefore, these lands can be utilized for the cultivation of Colocasia esculenta. Especially in waterlogged areas in the wet zone, where the other crops could fail.
5. Southwestern part of the country, known as the "wet zone", received an annual rainfall of 2,500 mm. Most of the southeast, east, and

northern parts of the country comprise the "dry zone", which receives between 1,200 and 1,900 mm of rain annually covering two-third of the country. This area is suitable for the cultivation of Taro. when getting little precipitation crops can be cultivated under irrigation.

6. Taro crop needs low inputs, low labor compared to other crops, and it has low pests and diseases. Therefore, the cost of production and the risk are low in Taro cultivation.
7. Taro acts as a nutrient security crop. There is a high potential as a home garden crop in small quantities. Therefore, this will help to increase food security at family level. Taro can be harvested within five months, whereas other root and tuber crops need around 8 months.
8. Most of the time Taro is used for medicinal purposes. Therefore, this will help in the promotion of "Ayurvedic" Medicine.
9. By increased attention on taro research will improve better understanding and contribution to the crop and increase food security, health, and economic empowerment in Sri Lanka.

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Chapter 10

Advances in the Production Technologies of Taro in India

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Abstract

Taro [*Colocasia esculenta* (L.) Schott] is an important tropical tuber crop widely cultivated in different states of India. Eddoe (*Colocasia esculenta* var. *antiquorum*) and dasheen taro (*Colocasia esculenta* var. *esculenta*) are cultivated under upland rainfed conditions or lowland rainfed conditions. Swamp taro (*Colocasia esculenta* var. *stoloniferum*) is cultivated under waterlogged conditions. Extensive research has been conducted on production, protection (pest and disease management) of taro. Agro-techniques including water and nutrient requirements have been worked out. Taro-based intercropping systems and integrated farming systems with improved varieties of vegetables and pulses can significantly enhance farmers′ income. Taro also responds well to organic production. It is adapted to marshy and waterlogged conditions and can tolerate submergence by flood but cannot withstand high-temperature stress (40°C). Its photosynthesis was not affected up to 1000 ppm CO_2. Therefore, it can grow in high CO_2 environment.

Introduction

Eddoe (*Colocasia esculenta* var. *antiquorum*) and dasheen taro (*Colocasia esculenta* var. *esculenta*) are cultivated under upland rainfed conditions or lowland rainfed conditions. Swamp taro (*Colocasia esculenta* var. *stoloniferum*) is cultivated under waterlogged conditions. Eddoe taro is propagated vegetatively, using whole corms or cormels whereas, swamp taro is propagated through stolons. It grows under wide range of conditions, varying from wetland to well-drained uplands under irrigated or rain-fed conditions. The productivity of corms and cormels varies from 5 to 40 metric tonnes/ha (mt/ha) whereas, the crop duration period varies between 5 and 18 months depending upon varieties and agroclimatic conditions (Kay and Gooding, 1987). Taro productivity varied among Africa (5.36 t/ha), Asia (16.79 t/ha), Egypt (35.96 t/ha), China (19.3 t/ha), Japan (12.50 t/ha) and U.S. (11.26 t/ha). Yields in Pacific island countries ranged from 19.99 t/ha for Fiji to about 7.69 t/ha for Papua New Guinea. The global production of taro has risen considerably from 5.5 Mt in 1991 to more than 10 Mt in 2016 (FAO 2018). The world production of taro has been estimated to be 11.8 Mt per annum from about 2 Mha with an average yield of 6.5 t/ha (FAO 2010). Global taro production reached 10.1 Mt harvested from 1.5 Mha in 2014, resulting in an average yield of 6.95 t/ha. Recent estimates indicated that it grew in an area of 1.66 Mha with a production of 10.64 Mt and productivity of 6.41 t/ha (FAO 2018) (Table 1A, 1B, 1C).

Taro is grown in 50 countries of the world. Area, production and productivity of taro during 2016, 2017 and 2018 are given in table 1. African continent occupies first position with an area and production of taro accounting for 89% and 73% of total world's taro production followed by Asia (8 and 22%) and Oceania (3% and 4%). Even though taro area and production are more in Africa, productivity is quite low (5 t/ha) which is lower than the world average (6 t/ha). Nigeria accounted larger area under taro (52%) among all the taro growing countries in the world with an annual output of 43%. China and Japan are the major taro-growing countries in Asia.

Table 1 A. Area, production and productivity of taro in the world (2016)

Continent	**Country**	**Area ('000 ha)**	**% of total**	**Production ('000 t)**	**% to total**	**Yield (t/ha)**
World	Total world	1711.88	100.00	10220.61	100.00	5.97
Asia	Total	136.72	7.99	2268.99	22.20	16.60
	China	95.91	70.15	1860.36	81.99	19.4
	Japan	12.20	8.92	154.6	6.81	12.67
	Philippines	15.14	11.08	107.57	4.74	7.10
	Thailand	10.62	7.77	100.53	4.43	9.46
Africa	Total	1517.45	88.64	7476.48	73.15	4.93
	Cameroon	241.51	15.92	1803.67	24.12	7.47
	Ghana	200.49	13.21	1301.18	17.40	6.49
	Nigeria	793.47	52.29	3233.85	43.25	4.08
Americans	Total	8.30	0.48	74.73	0.73	9.00
	Dominica	1.27	15.35	12.39	16.58	9.72

Continent	Country	Area ('000 ha)	% of total	Production ('000 t)	% to total	Yield (t/ha)
	French Guyana	1.42	17.06	3.92	5.25	2.77
	Nicaragua	4.92	59.23	47.91	64.12	9.75
Oceania	Total	49.41	2.89	400.42	3.92	8.10
	American Samoa	2.74	5.55	10.18	2.54	3.71
	Fiji	1.92	3.88	38.38	9.58	20.00
	Papua New Guinea	35.95	72.75	270.70	67.61	7.53
	Samoa	4.82	9.76	26.01	6.50	5.39
	Solomon Islands	2.62	5.30	45.45	11.35	17.36

Table 1 B. Area, production and productivity of taro in the world (2017)

Continent	Country	Area ('000 ha)	% of total	Production ('000 t)	% to total	Yield (t/ha)
World	Total world	1724.18	100	10221.96	100	5.93
Asia	Total	135.63	7.87	2273.62	22.24	16.76
	China, mainland	95.24	70.22	1865.36	82.04	19.59
	Philippines	15.01	11.07	109.37	4.81	7.29
	Japan	11.94	8.80	150.05	6.60	12.57
	Thailand	10.66	7.86	102.37	4.50	9.60
Africa	Total	1530.84	88.79	7466.47	73.04	4.88
	Nigeria	831.32	54.30	3250.86	43.54	3.91
	Cameroon	226.83	14.82	1847.12	24.74	8.14
	Ghana	183.96	12.02	1200.24	16.08	6.52
Americans	Total	7.52	0.44	72.60	0.71	9.66
	Nicaragua	4.40	58.46	42.57	58.63	9.68
	Dominica	1.25	16.64	12.29	16.93	9.83
	French Guiana	1.14	15.18	4.05	5.58	3.55
Oceania	Total	50.19	2.91	409.27	4.00	8.16
	Papua New	36.51	72.74	274.39	67.04	7.52

Continent	Country	Area ('000 ha)	% of total	Production ('000 t)	% to total	Yield (t/ha)
	Guinea					
	Samoa	4.60	9.16	24.59	6.01	5.35
	Solomon Islands	2.64	5.26	45.90	11.22	17.39
	American Samoa	2.86	5.71	10.97	2.68	3.83
	Fiji	2.15	4.28	42.99	10.50	20.00

Table 1 C. Area, production and productivity of taro in the world (2018)

Continent	Country	Area ('000 ha)	% of total	Productio n ('000 t)	% to total	Yield (t/ha)
World	Total world	1660.17	100	10639.85	100	6.41
Asia	Total	137.65	8.29	2310.51	21.72	16.79
	China	97.33	70.71	1910.56	82.69	19.63
	Japan	11.34	8.24	141.80	6.14	12.50
	Philippines	14.92	10.84	107.96	4.67	7.23
	Thailand	11.43	8.3	104.60	4.53	9.15
Africa	Total	1468.19	88.44	7874.57	74.01	5.36
	Cameroon	222.83	15.18	1901.51	24.15	8.53
	Ghana	223.50	15.22	1460.94	18.55	6.54
	Nigeria	715.86	48.76	3303.12	41.95	4.61
Americans	Total	5.07	0.31	42.77	0.40	8.43
	Dominica	1.29	25.39	12.39	28.98	2.81
	French Guyana	1.39	27.37	3.90	9.11	24.80
	Nicaragua	1.33	26.22	12.93	30.23	4.74
Oceania	Total	49.26	2.97	412.00	3.87	8.36
	American Samoa	2.82	5.73	10.35	2.51	3.66
	Papua New Guinea	35.38	71.83	271.99	66.02	7.69
	Samoa	4.59	9.32	25.12	6.10	5.47
	Solomon Islands	2.68	5.44	45.93	11.15	17.13

Source: Authors calculations based on FAOSTAT (FAO, 2019).

Most of the global production comes from developing countries characterized by smallholder production systems relying on minimum external resource input (Singh et al., 2012). The world Gross Production Value (GPV) of taro increased from US$ 1,946 million in 1991 to US$ 4,100 million in 2014 whereas, in Asia, the Gross Production Value (GPV) of taro increased from US$ 1,376 million in 1991 to US$ 2,160 million in 2014 (Gupta et al., 2019).

In India, taro is widely grown during rainy season (March to August) from the foothills of Himalayas to the coastal belt in Southern peninsular region. In India, it is grown in the homestead gardens or commercially grown in localized pockets in different districts such as Janshi, Farookhabad, Uttar Pradesh; Khandwa and Indore, Madhya Pradesh; Nayagarh, Cuttack, Odisha; East Godavari, West Godavari, Krishna and Guntur, Andhra Pradesh; 24-Paraganas, Nadia, West Bengal; Pathanamthitta, Alappuzha, Kerala; and Bastar, Kanwardha, Jaspur Chattishgarh (Shankar et al., 2016). In Rajasthan, taro is the choice tuber crop in Hadoti region (eastern Rajasthan in Jhalawar, Kota, Bundi and Baran). West Bengal, Odisha, Kerala, Uttar Pradesh and Madhya Pradesh are the major taro growing states in India (Table 2).

Table. 2. Area, production and productivity of taro in India (2009-2010)

State	Area (ha)	Production (Mt)	Yield (t/ha)
West Bengal	18543	288672	15.57
Kerala	8804	132060	15
Uttar Pradesh	7096	110635	15.59
Madhya Pradesh	4560	91200	20
Bihar	846	9577	11.32
Andhra Pradesh	700	14000	20
Tamil Nadu	478	5736	12
Punjab	422	8290	19.64
Rajasthan	275	825	3
Other states	10000	15000	15
Total	51724	810995	15.68

It was grown in an area of 51,724 ha producing 810,995 tones with productivity of 15.68 t/ha during 2009-2010 (Srinivas et al., 2012) but a recent report indicates a little increase in area of production (52,000 ha) with reduction in production (654,000 t) and productivity (12.57 t/ha) (Ramdeen Kumar et al., 2019). Corm and cormel yield of improved varieties varies between 18 and 20 t/ha (Singh and Samajdar, 2014). It is grown as pure stand (in Madhya Pradesh, Odisha and some parts of Andhra Pradesh) as well as inter-crop along with ginger or turmeric in Baruvasagar in Uttar Pradesh; along with rice and maize in Odisha; and along with greater yam in Andhra Pradesh.

Swamp taro is cultivated under waterlogged conditions. In India, about 11.6 million ha of land area is either waterlogged or prone to waterlogged conditions (Velayutham and Bhattacharya 2006) and significant portion of this vast land remains non-arable due to unfavorable soil and water regimes. In the mainland areas, this situation is caused mainly due to introduction of irrigation facilities in arid and semiarid areas whereas, in coastal areas waterlogging is mainly due to intense rainfall coupled with inadequate drainage or in sites with topographical depressions leading to submergence or swampy conditions (Roy Chowdhury et al., 2006). The yield of swamp taro stolon reaches its maximum at 6 to 7 months after planting and may vary from 10.19 to 20 t /ha among high-yielding varieties (Roy Chowdhury et al., 2012) or from 20 to 26 t/ha (Palaniswami and Shirley, 2006). The swamp taro also produces underground corm/rhizome along with petioles known as 'caudex' and is used as vegetables.

In the first paper we reviewed the genetic diversity and utilization aspects of taro. The present paper reviews the R & D on taro in India covering production, pest and disease management, and suggests recommendations for further R & D activities that could be useful in upscaling taro production among SAARC countries.

Production

Planting season

Farmers have been growing taro for several generations in the past a wide range of agro-ecological conditions. Taro requires warm moist and humid conditions. In natural habitats it is commonly found growing near water sources. This crop also survives well at high altitudes on hills (up to 3000 m amsl) if frost-free conditions prevail during the cropping season. Annual rainfall of 700-1500 mm well distributed during growing period is ideal for optimum tuber yield.

Time of planting is not a major factor in tropical regions provided sunlight and moisture are adequate. When the crop is rainfed, planting should be scheduled to coincide with the rainy/monsoon season. Where irrigation facilities are available, planting can be done any time of the year. In the experimental farm at ICAR-CTCRI taro planted during May and June produced significantly higher cormel yield as compared to other monthly plantings under rainfed conditions (Table 1).

Table 1. Influence of time of planting on growth and yield of taro var. Thamarakannan.

Time of planting	Leaf area index	No. of cormels/plant	Cormel yield (t/ha)	Mother corm yield (t/ha)
May	1.19	16.0	13.5	2.9
June	1.25	15.7	14.7	3.2
July	0.67	9.1	6.5	1.4
August	0.50	5.3	3.5	1.1
September	0.27	3.8	2.4	1.4
October	0.35	3.8	3.3	1.4
November	0.49	1.5	1.2	1.3
CD (P=0.05)	-	-	2.6	-

Source: CTCRI (1982)

However, the recommended planting seasons for different states are June and February for Bihar and eastern Uttar Pradesh; April-June for Kerala; June and February for Andhra Pradesh; May-June and February for Tamil Nadu; June, October and February for Odisha and April for Assam and West Bengal (Nedunchezhiyan and Sahoo, 2019).

Upland dasheen types are invariably planted during February-March under irrigated conditions, but lowland dasheen types are planted with the onset of monsoon (Misra et al., 2005). Swamp taro is planted during April in Assam and West Bengal.

Method of planting

Field preparation involves proper plowing and turning of soil till a fine tilth is created followed by formation of any one of the methods depending on the soil type such as pit, mounds, and ridge and furrow. In general, ridge and furrow system is more common. The flat-bed method can also be adopted under upland conditions having good drainage. Planting in small pits is good in flatbed planting (Nedunchezhiyan and Sahoo, 2019). Furrow planting is superior to other methods due to better soil moisture retention (Joseph et al., 1981). In dasheen type, pits are made for planting and as the plants grow, the pits are filled with the surrounding soil to form a ridge or mound by the later stages crop growth. In swamp taro, plantlets produced on the tip of the stolons are transplanted. In Odisha, a few varieties of swamp taro such as Panisaru-I and Panisaru-II are transplanted in puddled fields like paddy (Nedunchezhiyan et al., 2018a). Seedlings are raised in nursery at 20-30 days before transplanting. In the case of delay in transplanting or overgrowth in nursery, leaves are clipped (removed) and seedlings with petiole are transplanted. Depth of planting does not make any marked effect on cormel yield. However, planting seed material at a depth of 5-10 cm is most accepted practice (Mohankumar et al., 2000; Nedunchezhiyan and Sahoo, 2019). Very deep planting not only delays sprouting but in due course the planting material gets rotten.

Plant spacing

Optimum plant spacing for taro in Punjab was identified as 45 cm x 30 cm or 60 cm x 20 cm (Purewal and Dargen, 1957a). A spacing of 60 x 45 cm was identified for Kerala (Mohankumar et al., 1976) and 60 cm x 20 cm for Uttar Pradesh (AICRPTC, 1998). In general, wider spacing of 60 cm x 45 cm is recommended for taro during *Kharif* (Nedunchezhiyan and Sahoo, 2019). Planting of cormels should be done at 45 cm spacing on ridges made 60 cm apart. Under protective irrigation during *rabi* or summer season closure planting of 45 x 30 cm spacing can be adopted. High-density planting (45 cm x 30 cm) is also effective but its seed requirement is very high (1.5-2 t/ha). The spacing is also determined by the availability of water supply and extent of solar radiation received (Nedunchezhiyan and Sahoo, 2019). Wider spacing is adopted for dasheen and swamp taro. In *dasheen* type, a spacing of 60 cm x 45 cm is recommended (Misra et al., 2005) whereas, a plant spacing of 60 cm x 75 cm is followed for swamp taro (Chowdhury et al., 2012).

Planting material

Taro is a vegetatively propagated crop. Mainly the whole small corms, corm pieces and cormels are used for planting. Occasionally, stem cutting often called 'head sett 'or' hub' consisting of the corm apex plus the lower 15-30 cm of the attached petioles are used for propagation. In tropical areas, selection of planting material and planting of new crop is followed closely after harvest since the old crop provides planting material for the new crop. Mohankumar and Sadanandan (1988a) reported that in taro, both corm and cormels are equally suited as planting material. In dasheen type, usually cormels are rudimentary and therefore, the cut pieces of corm are used as planting materials.

Taro is propagated mostly by small cormels weighing 20-25 g. Medium size cormel of 35-45 g was found optimum under Kerala conditions (Joseph et al., 1981). Plant growth parameters, yield attributes and yield increase with increasing seed size (Singh et al., 2016; Kalita et al., 2018) (Table 2). Large cormels having more reserve food principally results in taller plants, early canopy closure and maximum leaf area which helps to produce greater biomass and yield. Cormels weighing 30 g are economic planting material of taro resulting in higher net return with maximum (2.12) benefit-cost ratio.

Table 2. Effect of weight of seed cormel on plant height, no. of cormels per plant and yield in var. Punjab Arvi-1.

Weight of seed cormel (g)	Plant height (cm)	No. of cormel/plant	Cormel yield (t/ha)
	2011-12	2011-12	2011-12
>75	81.9	11.1	31.4
60-75	70.9	10.65	27.15
45-60	44.65	9.15	22.4
30-45	37.15	7.4	16.75
<30	29.3	6.4	10.9
CD (0.05)	5.75	1.3	2.15

Source: Singh et al., (2016)

In dasheen type, cut pieces of corms weighing 25-30 g are used as planting material (Misra et al., 2005). In dasheen taro, microsett can also help for rapid propagation. From one kilogram of dasheen taro corm, 73 microsetts containing sprout buds of 1-2 g size can be produced. These microsetts had on average 70% sprouting and produced 12 to 19 t/ha corm yield (Ravi and Chowdhury 1999). Although 70 microsetts containing sprout buds of 0.5 g size can be obtained per one kilogram of corm, these microsetts had on an average 17% sprouting under *in vivo* conditions (Ravi and Chowdhury 1999). Therefore, they need to be cultured *in vitro* for improving their efficiency. In swamp taro, plantlets produced at the tip of the stolons are used for planting (Misra et al., 2005).

Soil and nutrient requirements

Taro can be grown in all types of soils but it prefers deep well-drained, friable loams particularly alluvial loams for its better growth and productivity. Well-drained and fertile sandy loam soil is ideally suited for its cultivation. It also comes up well in fertile loamy to clay loam soil. It can stand well in heavy soils and withstand waterlogged conditions in wetlands. It can withstand waterlogged and reduced aeration conditions, since taro can transport O_2 from the leaves to the roots through aerenchyma tissues, the gas space for effective transportation of oxygen under hypoxia conditions and oxidation of rhizosphere surrounding root tips (Abiko and Miyasaka 2020). Some of the cultivars (Pani Saru I and Pani Saru II) are adapted to water-logged fields and others to upland conditions. The soil pH of 5.5 to 7 is ideal.

Nutrient management

A crop response to fertilizer is higher in soil with low nutrient contents than soil with high nutrient reserve. Taro is highly responsive to fertilizers. The studies indicating the effect of major, secondary and micronutrients alone, together and in combination with farmyard manure (FYM) on growth characters, yield and yield attributes, plant nutrient uptake, soil physicochemical properties and biochemical properties of taro tubers are briefly summarized below:

Major Nutrients

Effect on tuber yield

Application of 50-100 kg N/ha increased plant height, LAI and cormel yield and resulted in economic yield at 100 kg N/ha (Purewal and Dargan, 1957b). For early vegetative growth, high LAI and significantly more yield, higher level (80 kg N/ha) of nitrogen is required (Mohankumar and Sadanandan, 1989). Taro cormel/ corm yield increased with increasing levels of N, with the maximum yield at 224 kg/ha N but the economic optimum was determined at 200 kgN/ha (Mathur et al., 1966a). Taro did not respond to phosphorus fertilizer application for favoring plant growth and cormel yield (Purewal and Dargan, 1957b; Pillai, 1967; Mohankumar and Sadanandan, 1989). Taro's yield response to phosphorus application was inconsistent and highest yield was obtained at 50 kg P_2O_5/ha (Mohankumar and Sadanandan, 1989). The vegetative growth and yield of taro show positive response to application of potassium fertilizers. The plant height, LAI and cormel yield increased with increase in the level of potassium application up to 100 kg K_2O/ha (Mohankumar and Sadanandan, 1989). However, there was no effect on height, number of suckers and LAI up to 120 kg K_2O/ha, cormel yield increased linearly (Pillai, 1967). In the laterite sandy clay loam soils of Kerala the cormel to corm ratio and the number and size of cormels in taro were improved by N and K applications (Ashokan and Nair, 1984). They further stated that the total corm/cormel yield was highest with N and K @120 kg/ha each. Cormel yield was highest at @ 80 kg/ha each of N and K and corm yield was highest under N and K @ 80 and

120 kg/ha respectively and determined the economic optimum doses of N and K_2O as 89 and 79 kg/ha respectively. Application of P @ 50 kg/ha had significant influence on the number and length of tubers significantly affecting the tuber yield without any effect on the girth of tubers (Pillai, 1967). Moreover, K fertilizers @ 120 kg/ha increased the corm and cormel yield significantly without significant effect on the size and shape of tubers. Substantial influence of K on cormel size up to 80 kg/ha K_2O (Ashokan and Nair, 1984). N and K significantly affected cormel yield up to 80 and 100 kg/ha with cormel yield as 12.3 and 11.4t/ha respectively but P had no effect and fixed the economic optimum based on response surface as 80 kg N, 50 kg P_2O_5 and 100 kg K_2O (Mohan Kumar, 1989). At Faizabad, UP, application of N @80 kg/ha in combination with K @ 120 kg/ha significantly increased the tuber yield (Verma et al., 1996). Optimum dose of N and K for maximum economic cormel production arrived as 120 and 60 kg/ha (Premraj et al., 1980). Application of NPK @ 40:60:120 kg/ha resulted in highest cormel yield and best tuber quality cormels in taro (Ramaswamy et al., 1982).

Effect on corm/cormel quality parameters

Mohandas and Sethumadhavan (1980) reported high dry matter with higher levels of N. Starch content of tubers increased at higher levels of K application whereas oxalate content in tubers increased at higher levels of N and K application (Premraj et al., 1980). However, N application had no significant effect on the oxalate content (Mandal et al., 1982). Dry matter percentage of corms was not significantly influenced while starch content increased significantly with higher levels of N and K while oxalic acid content decreased with increasing levels of K (Ashokan and Nair (1984). Tuber and total dry matter production increased significantly up to 80 kg N, 100 kg K_2O per ha and levels of P_2O_5 had no significant effect on these characters while K significantly increased starch content of tubers (Mohan Kumar and Sadanandan, 1989). P fertilizers had no significant effect on starch content of tubers, but dry matter content increased up to 50 kg/ha P_2O_5 and K had significant effect on the starch content of tubers (Pillai, 1967).

Effect on growth characters

Application of N and K had significant effect on increasing plant height but P did not affect this character. Application of N had a significant effect on increasing LAI up to 80 kg/ha (Mandal et al., 1982). Varying levels of N and K had significant effect in increasing plant height and LAI, but graded doses of P did not have any significant effect on these traits, while application of K had a linear effect on LAI (Mohan Kumar and Sadanandan, 1989). Lower levels of P do not affect height and leaf area of the plant, but higher levels of P and K increase the number of leaves while K did not affect the height of the plant, number of suckers and leaf area up to 120 kg/ha (Pillai, 1967). The height of the taro plant and number of leaves produced per plant was not significantly influenced by higher levels of N or K (Ashokan and Nair, 1984). In the laterite soils of Kerala, application of manures and fertilizers on plant growth was found significant at 3 MAP (Sheeba et al., 2015).

Effect on soil Physico-chemical properties

Studies on the residual status of soil NPK after field experiments for two seasons under taro with different levels of N, P and K resulted in considerable reduction in N (15-20%) and K (10-15% with substantial build-up of P (15-20%) over the initial status (Mohan Kumar and Sadanandan, 1991).

Effect on plant nutrient uptake

A crop of taro producing 17 t/ha of corm and cormel with a total dry biomass production of 6.2 t/ha removes 128.4 kg N, 19.2 kg P and 135 kg K (Kabeerathumma et al., 1987). The peak demand for N and K for taro was during 3 MAP and the P content in the plant part was maintained almost constant up to 3 MAP and there is high removal of N and K (Kabeerathumma et al., 1984, 1985). Potassium was utilized in higher proportions compared to N and P at all growth stages indicating a higher K requirement by the crop (Kabeerathumma et al., (1987). At 3MAP, which is considered as the peak vegetative growth and cormel formation stage of the crop, the N and K utilization were almost same. P utilization was found higher at later stage indicating its utility at cormel bulking stage. Among the three nutrients, P uptake was lowest at all stages of growth. The content of N, P and K in shoot was higher at all stages of growth.

The NPK uptake requirements of taro for specific yield target based on Site-Specific Nutrient Management (SSNM)-QUEFT (Quantitative Evaluation of Fertility of Tropical Soils) model was 12.97, 2.75 and 17.47 kg/t of cormel yield respectively, suggesting an average NPK ratio in the plant dry matter of about 4.7:1:6.4 (Jinimol Raju and Byju, 2019). The optimal internal efficiencies of NPK for balanced nutrition arrived as 77.07, 364.07 and 57.23 kg cormel per kg N, P and K removed. Based on the nutrient availability from innate nutrient supply and fertilizers applied, crop nutrient uptake at different growth periods N, P and K requirements were estimated for attaining 30 t/ha corm+cormel yield.

The total plant N uptake at 120 DAP was 43.6, 59.1, 62 kg/ha at application of 40, 80, 120 kg/ha N, the total P uptake was 6.9, 7.9 and 8.4 kg/ha at application of 25, 50 and 75 kg/ha P_2O_5 and total K uptake was 57.8, 72 and 85.2 kg/ha respectively, at application of 50, 100, 150 kg/ha K_2O, respectively (Mohan Kumar, 1989). As regards the NPK uptake pattern in taro at different levels of NPK, the total N uptake increased significantly up to 80 kg/ha, but increasing levels of P and K application had significant effect on the uptake of these nutrients at all levels (Mohan Kumar and Sadanandan, 1990a).

Secondary and micronutrients

Integrated application of lime along with farmyard manure (FYM), 50% of the recommended dose of NPK and $ZnSO_4$ @ 12.5 kg/ha resulted in the maximum dehydrogenase activity (2.05 µg TPF/g/hr) and fluorescein diacetate hydrolysis assay (1.86 µg/g/hr). Vesicular arbuscular mycorrhizae (VAM) along with lime, FYM and 50% of the recommended dose of NPK resulted in the highest soil acid and alkaline phosphatase activities to the tune of 77.67 and 51.18 µg para nitrophenol (PNP)/g/hr, respectively (Laxminarayana, 2016).

The peak content of Ca in all plant parts was during the early crop growth stage and thereafter it declined. Mg concentration was maximum in the early growth stage and thereafter it declined in leaf and petiole. Mg removal by the crop was maximum at the harvest stage. Sulfur content in tuber increased towards maturity and the total removal was maximum at 90-120 DAP. In the case of micronutrients *viz.,* Fe and Mn, the contents are least in cormels and decreased in leaf towards maturity. Highest uptake of these nutrients was at 90-120 DAP and the shoot portion contains 75% of Mn. In the case of Zn and Cu, there is an increase in their content with increase in the age of the crop and the peak content was observed at 150 DAP. The percent removal of Zn and Cu progressively increased with maturity and the maximum percent removal was observed at 120-150 DAP. A crop of taro producing 17 t/ha of corm and cormel with a dry biomass production of 6.2 t/ha removes 30.42 kg Ca, 15.87 kg Mg, 11.80 kg S, 10.25 kg Fe, 1.69 kg Mn, 647 g Zn and 93 g Cu from the soil (Kabeerathumma et al., 1987)

Mode and time of application of nutrients

The existing Package of Practices (PoP) recommended by Kerala Agricultural University (KAU) is two split doses of fertilizers *viz.,* full dose of P and half dose of N and K within a week after sprouting and the remaining half dose at one month later (KAU, 1978, 1996). Split application of fertilizers at one and two MAP is better than three splits concerning cormel yield (Sheeba et al., 2015). Time of application of N and K had significant effect on LAI with three split applications (Mohan Kumar, 1989). Time of application of different levels of N in taro significantly influenced the cormel at 80 kg N/ha under two splits preferably within 3 MAP (Mathur, 1966b). Three split applications of N and K significantly increased CGR (8.6 g $m^{-2}day^{-1}$on dry matter basis), cormel yield, uptake of N and K, starch content of cormels (Mohan Kumar, 1989). However, application of N in three split doses, 50% at the time of planting and the rest in two equal splits at 40^{th} and 60^{th} day after planting (Sarnaik and Peter, 1977) or three split applications of N and K at the rate of one-third dose when 50% sprouting occurs, second one-third one month later and the remaining one-third one month after the previous application (Mohankumar et al., (1990a) have also been recommended for achieving high yield. Basal application of 50% of recommended N, K and 100% P through straight fertilizers in soil and top dressing with foliar sprays of urea and sulfate of potash (SOP) at 2% concentrations to supply the remaining 50% N and K or 50% N, P, K in soil and foliar nutrition with 19:19:19 and 13:0:45 (KNO_3) at 5% concentrations, four times at weekly intervals from second month onwards resulted in higher plant growth, corm and cormel number and size, and yield respectively to the tune of 65 and 44% more than the yield obtained with recommended package of practice as soil application and also fetched the maximum net return and benefit-cost ratio (Sheeba et al., 2015).

Plant critical level of NPK

Critical level of nutrients in plants is sufficiency range of nutrients, below which there can be deficiency resulting in the manifestation of nutrient disorders. The plant will give positive response to the application of that particular nutrient if the plant nutrient concentration is below the critical level. The critical level of N, P and K in taro was determined as 2.07-3.93%, 0.32-0.35% and 1.84-2.13% based on the equation fitted between yield and nutrient concentrations (Mohan Kumar, 1989).

Integrated nutrient management (INM) practice and its impact on different parameters

Highest taro yield was obtained at FYM 12.5 t/ha as basal along with a fertilizer dose of 80 kg N and mulching with green leaf at 12 t/ha (Mohankumar et al., 1990a). However, for Odisha, application of $N:P_2O_5:K_2O$ @ 100:80:80 kg/ha was the best (Misra et al., 2005). A fertilizer rate of 40-80 kg N, 10 kg P_2O_5 and 40-80 kg K_2O per hectare with split application of N and K has been recommended for Kerala (Mohan Kumar and Sadanandan, 1989; Mohan Kumar et al., 1990a). At an experimental research station in Jharkand, application of N-P_2O_5-K_2O @ 200 kg/ha resulted in significantly superior (corm yield 11.5 t/ha) as compared to corm yield attained with the application of N:P:K (19:19:19) @ 300/100 kg/ha (Das et al., 2018).

Cormel yield was highest when N-P_2O_5-K_2O fertilizers were applied @ 80-50-80 kg/ha respectively (Ashokan and Nair, 1984; Sen and Roychowdhary, 1988). The optimum blanket recommendations are 80-50-100 kg/ha of N-P_2O_5-K_2O for Kerala (KAU, 1996), 80:20-60:80-100 kg/ha for Andhra Pradesh (AICRP, TC 1987; Lakshmi et al., 2018) and 120-60-120 kg/ha for Maharashtra (Nedunchezhiyan and Sahoo, 2019). In Odisha, soil test-based fertilizer (85–43–66 kg/ha of N-P_2O_5-K_2O respectively) application resulted in 9% higher yield than the yield obtained with blanket recommendation of fertilizer dose at 80–60–80 kg/ha of N-P_2O_5-K_2O respectively (Laxminarayana, 2016). However, in Odisha taro responded well to 100–80–80 kg/ha of N-P_2O_5-K_2O respectively (Misra et al., 2005). In Tamil Nadu, application of 40:60:120 kg/ha of N-P_2O_5-K_2O resulted in highest cormel yield and best quality cormels (Ramaswamy et al., 1982). Maintenance of higher levels of nitrogen (both organic and inorganic) encourages the initiation of more stolons at a faster rate from initial stage and maintained their superiority throughout the season resulting in higher production (Sen et al., 1998).

The Integrated Nutrient Management (INM) evolved at Raipur, Chattisgarh with the application of vermicompost @ 200 kg/ha along with 75% recommended dose (N:P_2O_5:K_2O@ 80:50:100 kg/ha) significantly increased total corm and cormel yield, gross return, BC ratio and quality parameters (Jurri, 2008). Application of vermicompost @1t/ha along with FYM @ 10 t/ha and 50% of the recommended dose (N:P2O5:K2O @ 80:50:100 kg/ha) of NPK resulted in high yield and good quality cormels at ICAR Research Complex for North Eastern Hill Region of Meghalaya (Verma et al., 2012). The economic dose of FYM, N and K for maximum yield and better quality of *dasheen* type taro at Faizabad, was determined as FYM @15 t/ha and N and K_2O @120 and 80 kg/ha (Prajapati et al., 2003). However, application of 80 kg N in combination with 120 kg K_2O per ha resulted in significantly higher net return per rupee investment. Taro responded well to NPK @ 100:50:100 kg/ha (Mandal et al., 1972). Mohandas and Sethumadhavan (1980) recommended a fertilizer dose of 120 kg N, 75 kg P_2O_5 and 150 kg K_2O/ha for taro. At Birsa Agricultural University, Bihar 10 t FYM, and 80:50:100 kg NPK are recommended for taro (Sarkar et al., 1996).

Application of recommended dose of N: P_2O_5: K_2O @ 80:60:80 kg/ha or vermicompost @ 1 t/ha and full dose of FYM @ 10 t/ha along with 75% of the recommended dose of NPK resulted as the best practice at the ICAR-All India Co-ordinated Research Project (AICRP) experimental station at Coimbatore (AICRP-TC, 2012). At AICRP experimental station in Faizabad, vermicompost @ 1 t/ha along with full dose of FYM @ 10 t/ha and 75% of the recommended dose of NPK was found as the best practice (AICRP-TC, 2012). Under West Bengal conditions, application of FYM @ 10 t/ha along with mustard cake @ 1 t/ha or vermicompost @ 1 t/ha and FYM @ 10 t/ha and 75% of the recommended dose of N: P_2O_5: K_2O @ 80:60:80 kg/ha was recommended for improving cormel yield of taro. Integrated nutrient management package involving application of vermicompost @ 1 t/ha or FYM @ 10 t/ha along with 50-75% of the recommended dose of NPK is better for improving the cormel yield of taro. Wherever groundnut cake or mustard cake is available in cheap, NPK fertilizers can be avoided completely by the addition of FYM @ 10 t/ha and groundnut or mustard cake @ 1 t/ha (James et al., 2018). In the experimental research station at Horticulture College and Research Institute, Tamil Nadu Agriculture University, application of 10 t FYM and NPK 80:60:80 kg per ha resulted in highest number (7) of cormels per plant and 13.15 t/ha cormel yield whereas application of one tone vermicompost + 10 t FYM and 75% of 80:60:80 kg NPK per ha resulted in 6 number of cormels per plant and 12t/ha cormel yield (Venkatesan et al., 2013). In the experimental farm at Assam Agricultural University, Jorhat, application of 1 tonne vermicompost + 10 t FYM and 75% of 80:60:80 kg NPK per ha resulted in highest number of cormels per plant (12) and cormel yield (17 t/ha) whereas application of 1 tonne vermicompost + 10 t FYM and 80:60:80 kg NPK per ha resulted in 12 number of cormels per plant and 14 t/ha cormel yield (Saud et al., 2013a, b). The variation in fertilizer recommendations concerning different experimental sites in different agro-climatic regions of the country can be attributed to the unique soil and climatic factors which in turn had a major role in affecting the cormel yield.

Conjunctive use of organic manure and soil test-based inorganic fertilizers not only enhanced the crop productivity and biochemical constituents of taro but also improved the microbial activities and soil physicochemical properties (Laxminarayana, 2016). Dehydrogenase and acid phosphatase activities were highly influenced due to the integrated application of lime, FYM and balanced chemical fertilizers and these enzymes had a greater contribution toward the yield and quality of taro under acidic Alfisols (Laxminarayana, 2016). Integrated use of mycorrhiza, inorganic and organic manures in an acid Alfisol resulted in significantly highest cormel yield (14 t/ha) with NPK @ 150% (Laxminarayana, 2016). Inoculation of Vesicular Arbuscular Mycorrhiza (VAM) combined with ½ N-P_2O_5-K_2O and FYM resulted in a mean cormel yield of 13.4 t/ha with an increase of 39% over that of ½ N-P_2O_5-K_2O however, liming further enhanced the cormel yield by 1.8% over that of VAM + FYM + ½ N-P_2O_5-K_2O (Laxminarayana, 2016). Fungal inoculation along with lime and ½ N-P_2O_5-K_2O had a greater impact on tuberization, resulting in higher cormel yields over that of inorganic fertilizers. *Piriformospora indica* is a beneficial endophytic root colonizing fungus that promotes nutrient uptake apart from resistance against biotic and abiotic stresses. The fungus colonizes both inter and intracellularly in rhizodermis and cortical areas of the root and does not invade the aerial parts and endodermis of the plant. In taro, incorporation of *P. indica* promoted growth in terms of plant height, number of leaves, leaf length and leaf breadth irrespective of varieties (Lakshmipriya et al., 2016a, b).

Highest cormel yield of 14 t/ha was recorded due to the integrated application of lime + FYM + ½ N-P_2O_5-K_2O + ZnSO4 with a yield response of 44% over that of ½ N-P_2O_5-K_2O at par with lime + FYM + N-P_2O_5-K_2O + MgSO4 (13.57 t/ha) with a yield response of 41% over that of ½ N-P_2O_5-K_2O (Laxminarayana, 2016). The mean yield response was the highest with ZnSO4 (22.8%), followed by MgSO4 (20%) and borax (18%). Addition of lime along with FYM, half of the recommended doses of N-P_2O_5-K_2O and micronutrients showed a significant rise in cormel yields over that of un-limed plots and the response between limed and un-limed treatments was the highest concerning Zn (5%), followed by boron (B) (4%) and Mg (1.7%). The highest yield response due to liming and addition of ZnSO4 and MgSO4 in these acidic soils is attributed to neutralization of soil acidity contributed to the higher absorption of all the essential nutrients from both native and applied sources (Laxminarayana, 2016). The blanket fertilizer recommendation for different states is enumerated in table 3.

Table 3. Fertilizer recommendations for taro in different states

State	FYM (t) + Fertilizer (kg/ha)	Source
Meghalaya	N-P_2O_5-K_2O 80-25-100	Singh and Samajdar (2014)
Jharkhand	N-P_2O_5-K_2O 57-57-57	Das et al., (2018)
	FYM 10t+N-P_2O_5-K_2O 80-60-80	Sengupta et al. (2018)
Kerala	FYM12t+N-P_2O_5-K_2O 80-25-100	Sunitha et al. (2018)
Andhra Pradesh	FYM10-12t+N-P_2O_5-K_2O 80-25-100	Lakshmi et al. (2018)

State	FYM (t) + Fertilizer (kg/ha)	Source
Maharashtra	N-P_2O_5-K_2O 120-60-120	Nedunchezhiyan and Sahoo (2019)
Tamil Nadu	FYM25t+ N-P_2O_5-K_2O 40-60-120	Velmurugan et al. (2018)
Odisha	FYM10-15t+N-P_2O_5-K_2O 80-60-80	AICRPTC (1987); Nedunchezhiyan et al., (2018a)
Bihar	FYM10-15t+N-P_2O_5-K_2O 80-60-80	AICRPTC (1987; Singh and Singh 2018)
Assam	FYM12t+N-P_2O_5-K_2O80-60-120	Saud et al., (2013a,b)
Uttar Pradesh	FYM12-15t+N-P_2O_5-K_2O 80-80-120	Chandra Deo (2018)
West Bengal	FYM10t+N-P_2O_5-K_2O 100-80-100	Mitra and Tarafdar (2018)
Andaman and Nicobar Islands	FYM12t+N-P_2O_5-K_2O 100-80-100 N-P_2O_5-K_2O 200-150-100 (swamp taro)	Sankaran et al., (2018)
Chhattisgarh	FYM 15-20t+N-P_2O_5-K_2O100-80-100	Deo Shankar and Singh (2018)

For dasheen taro at Faizabad, Uttar Pradesh optimum economic dose of FYM 15 t/ha and N and K_2O @ 120 and 80 kg/ha, respectively are recommended for higher yield and better quality (Prajapati et al., 2003). Application of FYM @ 8 t/ha as basal and N-P_2O_5-K_2O @ 52-60-63 kg/ha respectively applied in three split doses at 2nd, 5th and 8th months of the crop growth period resulted in high stolon yield in swamp taro (Chowdhury et al., 2012).

NPK recommendation for taro under intercropping with coconut

For getting high yield and net return from taro intercropped in coconut garden with 50% light infiltration, an N:P_2O_5: K_2O dose of 105:13:62 kg/ha resulted in higher cormel yield based on nutrient uptake and soil test values (Geetha et al., 2005).

Foliar nutrition in taro

Basal application of 50% of recommended N, K and 100% P through straight fertilizers in soil and top dressing with foliar sprays of urea and sulfate of potash (SOP) at 2% concentrations to supply the remaining 50% N and K or 50% N, P, K in soil and foliar nutrition with 19:19:19 and 13:0:45 (KNO_3) at 5% concentrations, four times at weekly intervals from second month onwards significantly increased plant growth, corm and cormel number and size and hence the yield respectively to the tune of 65 and 44% more than recommended PoP as soil application and fetched the maximum net returns and benefit-cost ratio (Sheeba et al., 2015).

Organic farming practices

Suja et al., (2015) using three varieties *viz*., Sree Kiran, Sreec Rashmi and Local, evolved the organic management practice for taro comprising of the use of organically produced planting materials, application of FYM @ 15 t/ha, neem cake @ 1 t/ha, biofertilizers *Azospirillum* @ 3 kg/ha, mycorrhiza @ 5 kg/ha and phosphobacteria @ 3 kg/ha, inter sowing of green manure cowpea @ 20 kg/ha and incorporation of green matter at 45-60 days, application of ash @ 2 t/ha at the time of incorporation of green manure cowpea.

Studies under organic vs. conventional farming in taro over five seasons at ICAR-Central Tuber Crops Research Institute, India, revealed that the organic system (10.6 t/ha) performed similar to that of conventional (11 t/ha), with slight yield reduction (-5%), equally good response of both elite and local varieties to organic management, lowering of bulk density improvement in water holding capacity (+19%) and porosity (+3%) of soil, better cormel quality with high dry matter, starch, sugars, P, K, Ca and Mg contents, high soil pH (+1.2 unit) and available P and soil organic C (+39%), exchangeable Ca, Mg, Fe, Mn, Zn and Cu status (Suja et al., 2014, 2017). Organic management resulted in net income of US$ 2,386/ha (Rs. 174,160/ha) as compared to conventional practice [US$ 1,727/ha (Rs. 126,040/ha)] (Suja et al., 2015). On-farm validation of the technology at seven locations in southern India revealed 29% increase in tuber yield under organic management and hence proved to be an eco-friendly alternative to conventional farming for stable yield and quality cormels as well as for maintaining soil health.

The evaluation of organic production technology in taro conducted at AICRP centers at Coimbatore, Ranchi, Jorhat, Kalyani, Dholi and Raipur during 2006-08 indicated variation in response with different centers mainly due to the specific soil and climatic condition of the different agro-climatic units (AEU's) where these experiments were conducted which in turn was having significant influence on cormel production. Application of vermicompost @ 200 kg/ha along with 75% recommended dose of NPK resulted best yield in most of the centers which were on par with vermicompost @ 200 kg/ha along with NPK @ 50% of the recommended dose. At Kalyani and Raipur, application of organics alone resulted in best yield as neem cake or mustard cake @ 5 t /ha along with FYM @ 10 t/ha (James et al., 2018). However, use of organic manures alone for 100% substitution was found to be most expensive, as the nutrient contents were lower in the organic sources and hence required in bulk quantities to satisfy the recommended doses of N, P and K in taro (Sheeba et al., 2015).

Mulching

Application of mulch soon after planting is beneficial for taro (Nedunchezhiyan and Sahoo, 2019). Green leaf mulching had a significantly increased taro yield due to an enhanced level of available nutrients to the crop (Mohankumar and Sadanandan 1988a, b). Mulching with leafy material reduces weed incidence, conserves moisture and increases corm and cormel yield (Singh and Samajdar, 2014). Paddy husk mulching resulted in highest cormel yield which was significantly higher than other mulches (AICRPTC, 1998).

Weeding

It is essential to keep the taro field clean and weed-free. Several annual crops are known to be sensitive to weed competition only during early growth, usually during the first 25-30% of their growing period. Initial slow growth and development of taro coupled with wider spacing make conditions favorable for early establishment of weeds in the cropped fields. A greater portion of the taro roots is seen within the depth of 2-8 cm in the soil (Mohankumar and Sadanandan 1990b). Being a shallow root system, taro has to compete for water and nutrients with the weeds almost in the same layer of the soil because most of the root system of weeds also concentrates on the top layer of the soil. Thus, weed competition severely affects the taro root development. Root length and root volume of taro are markedly reduced due to greater duration of weed infestation (Nedunchezhiyan and Satapathy, 2003). A drastic reduction in taro root volume due to nutsedge infestation up to 2-3 months after planting was recorded (Nedunzhiyan, 1995). Initial weed-free period up to 60 days after planting is essential for proper root growth and development in taro (Nedunchezhiyan and Satapathy, 2003). Also by this time root system is fully established for competition in the soil for water and nutrients.

However, the root length and volume increased with the increase in duration of weed-free period.

The effect of weed interference in taro prevents the development of optimum leaf area which in turn affects the production of necessary assimilates for tuber bulking. The presence of weeds throughout the crop growth period reduced taro yield by 60%. Besides delaying the normal process of cormel initiation in taro, weeds reduced cormel number per plant (Nedunchezhiyan et al., 2013). Losses caused by the weeds depend upon their density, dominance and ecological success. Twenty-three weed species were identified in *Kharif* taro field under Bhubaneswar (Odisha, India) conditions (Nedunzhiyan et al., 1996). A large number of weeds belonged to Poaceae, followed by Cyperaceae, Fabaceae and Rubiaceae. There were two weeds belonging to each of the families of Asteraceae, Euphorbiaceae and Tiliaceae. The remaining families Commelineceae, Amaranthaceae and Capparidiaceae possessed a single weed each. In acidic laterite soils poor in organic matter, nitrogen and potassium, *Celosia argentia*, *Digitaria sanguinalis* and *Cleome viscosa* were the dominant weed community (Nedunzhiyan et al., 1996). The taro yield was inversely proportional to the purple nutsedge (*Cyperus rotundus*) density (up to 200 nos./m^2) (Nedunzhiyan, 1995). The tuber yield was highest under weed-free conditions and was comparable with the infestation density of 10 and 20 nos./m^2 beyond which yield was drastically reduced.

Two manual weedings coinciding with the two split applications of fertilizers and earthing up and a third one at later stage of the crop growth are needed to produce significantly higher yield. Three-hand weeding resulted in significantly higher cormel yield than two, and there was no significant difference in yield between the three-hand weedings and the application of atrazine or simazine (Mishra and Mishra, 1985; Sarnaik and Peter, 1977).

Mulching of taro has been practiced to control weed and conserve moisture (Mohankumar and Sadanandan, 1988a; Singh et al., 2003). Maximum weed infestation (dry weed mass 573 g/m^2) occurs in taro fields without mulching (Singh et al., 2003). Black polythene mulching and 60 cm x 20 cm plant spacing resulted in effective weed control (dry weed biomass 97 g/m^2) in taro, but paddy straw mulching was found to be economical with less weed infestation and maximum corm yield as compared to field without mulching (Singh et al., 2003). The yield reduction in unweeded fields was due to due to cumulative effects of competition for available space and nutrients. The combined presence of taro and nutsedge resulted in depletion of soil N and K as compared to weed-free conditions (Nedunzhiyan, 1995).

Several herbicides have been recommended for weed control in taro field. Pre-emergence application of isoproturon @ 1 kg/ha controlled the weeds effectively in taro (Nedunchezhiyan et al., 2002). Application of atrazine or simazine or nitrofen @ 1 kg/ha as pre-emergence was also effectively controlled the weeds in taro field (Mishra and Mishra, 1985).

Taro being a moisture-loving crop favors weed growth throughout its growth period. Hence weed management, more preferably an integrated approach involving pre- and post-emergence herbicides, or herbicide along with hand weeding or use of suitable mulching materials like straw or ground cover sheets would help to control the menace.

Earthing-up is required immediately after weeding. Generally, two earthing-up operations are required first 7-8 days after sprouting and the second a month later. The top dressing of fertilizer is done along with earthing-up.

Desuckering

Desuckering is done at the time of second earthing-up. Only 3 suckers/plant should be left if the rainfall is not regular (Nedunchezhiyan and Sahoo, 2019). Cormel/ corm size and yield per plant can be increased by de-suckering the unhealthy suckers and retaining only the healthy suckers (CTCRI, 1982). Maximum yield can be attained when three healthy suckers are allowed to grow (Singh and Samajdar, 2014).

Water management

Irrigation

The growth and development of taro under upland conditions are likely to be similar to that of wetland conditions (Narzary and Rajendran 1999). There are two main production systems used in taro cultivation: under upland irrigated/rainfed conditions and lowland waterlogged conditions. Under rainfed conditions, supplementary irrigation by sprinkler or surface irrigation may be given during the dry spell.

Response to soil moisture

Taro is highly sensitive to water deficit stress (WDS) conditions either due to lack of irrigation or failure of rainfall. Abiotic stresses such as, soil moisture deficit, soil salinity and poor soil nutrient status decrease vegetative growth and productivity of taro. Production of taro, often underwater scarcity conditions, might cause up to 90% yield loss or total crop failure (Ravi and Chowdhury, 1997). The major factor limiting taro growth is the amount of soil moisture available to the crop during the growing season. The non-availability of water results in a cumulative effect of reduced leaf area, leaf area, leaf longevity, stomatal opening and dry matter production, and some other physiological parameters (Ravi and Chowdhury 1991, 1993a, 1997) and corm yield in taro (Ravi and Chowdhury 1996; Sunitha et al., 2013).

Many taro varieties can produce cormels of marketable size under rainfed conditions. Taro cultivars produced significantly higher corm yield in five months growth period under rainfed upland conditions (Ravi and Chowdhury, 1996). In these cultivars, the leaf area increased continuously up to four months and decreased at 6th month due to decline in available soil moisture because of reduced rainfall. Tuber differentiation in taro under upland conditions starts early and corm formation begins when the plant is about two months old. Under water deficit stress (WDS) conditions, taro showed significant reduction in leaf production. Leaf area and plant height of taro declined steeply under water deficit stress. Twenty-five percent of soil moisture saturation adversely affected the growth and corm yield of *eddoe* type of taro (Ravi and Chowdhury, 1991). Taro plants grown under 25% soil moisture saturation showed greater reduction in relative water content (RWC), total chlorophyll, sugar content and membrane stability in leaves. Accumulation of greater amount of proline in leaves under 25% soil moisture than under 50% and 100% soil moisture saturation indicated that plants under 25% soil moisture have undergone WDS stress than those under 50% and 100% soil moisture saturation (Ravi and Chowdhury, 1991, 1993b). Stomatal opening in the leaves was significantly reduced in taro plants grew under 25% soil moisture than those grew under 100% soil moisture (Ravi and Roy Chowdhury, 1993b). Taro plants grew under 25% of soil moisture saturation showed greater reduction in leaf area, growth, CGR, NAR, RGR and yield as well as greater stomatal closure than those grew under 50 and 100% of soil moisture saturation (Ravi and Chowdhury, 1990). Therefore, 50% soil moisture saturation can be considered as the critical level below which taro crop may experience water deficit stress and result in yield reduction (Ravi and Chowdhury, 1997). Taro has shallow root system and majority of the roots are confined to a lateral spread of 40 cm and depth of 9 cm in the soil (Mohankumar and Sadanandan 1990). Therefore, it is essential to retain adequate soil moisture in this root zone.

Polyethylene glycol (PEG)-mediated water deficit stress significantly reduced growth and other physiological parameters in taro genotypes both under *in vitro* and *in vivo* conditions. Thereby, taro genotypes varied under *in vitro* and *in vivo* PEG-mediated osmotic/WDS conditions at morphological, physiological, and biochemical levels (Sahoo et al., 2018). Under *in vitro* PEG-mediated WDS (-0.2 MPa) conditions, days to sprouting of cormel tip explants were delayed (14.3 d) followed by gradual growth retardation as compared to WDS -free control explants (5.4 d). PEG-mediated WDS had significant detrimental effect on the shoot proliferation in terms of number of leaves, roots, length of shoots and roots. Significant genotypic variation was observed in all the parameters except, the number of leaves and roots. The mean number of leaves varied from 2.0 to 2.3 in control explants whereas, it was reduced to one to two under PEG-mediated WDS stress. Plant height was reduced under PEG-mediated WDS. After six weeks of *in vitro* cultivation, control taro plantlets attained 4.5-6.25 cm height whereas, it was significantly reduced to 3.10-5.02 cm under PEG-mediated WDS conditions. Under *in vivo* conditions, taro plantlets cultured *in vitro* were subjected to PEG-mediated WDS. The leaf area ranged from 127.62 to 235 cm^2 among the genotypes under controlled conditions, which was significantly reduced to 125.02 to 217 cm^2 under PEG-mediated WDS. Reduction in leaf area negatively affected biomass production and yield. Significant reduction occurred in the relative water content (1.8-19.2%), chlorophyll stability index (4.6-22.4%), stomatal conductance (9.9-68.3%), transpiration rate (4.95-23.8%) and net photosynthetic rate (16.6-38.2%) while stomatal resistance increased (11.8-25%) in taro genotypes under PEG-mediated WDS as compared with control. Stomatal closure is a drought-avoidance mechanism that allows the plants to reduce water loss through transpiration. Stomatal closure also restricts the diffusion of CO_2 into leaves, influences stomatal conductance (g_s) and stomatal resistance (Rs) and thereby results in lower intercellular CO_2 concentration (Ci). This in turn resulted in the reduction of net photosynthetic rate (P_N). Chlorophyll stability index in leaves under control varied between 92.29 and 99 and it was further reduced to 72.16 - 88.98 under PEG-mediated WDS. The rate of decrease in CSI varied between 4.6 and 22.4%. Total soluble protein content in leaf tissues of taro genotypes varied between 31.32 and 58.15 mg/g in WDS-free control plants, which decreased to 15.57-50.13 mg/g in plants under PEG-mediated WDS. This is due to lowering of overall protein synthesis and/or increasing protein degradation. The proline content increased by 6.3 -77.8% under PEG-mediated WDS in the genotypes investigated. Total soluble sugar (TSS) and reducing sugar (RS) content in the leaf tissues were significantly reduced under PEG-mediated WDS due to reduction in P_N. Total phenols content significantly accumulated in leaf tissues of taro genotypes under PEG-mediated WDS conditions. The total phenol content varied between 43.1 and 26.5%. Antioxidative enzyme activities such as superoxide dismutase (SOD) and guaiacol peroxidase (GPX) significantly increased in plants under PEG-mediated WDS *in vivo* which effectively scavenges reactive oxygen species (ROS) and protects cellular structures from oxidative damage. Leaf SOD activity varied between 69.77 and 106.67 unit/mg protein in plants under PEG-mediated WDS conditions and between 95.2 and 202.27 unit /mg protein under PEG-mediated WDS. GPX under control condition varied between 0.10 and 0.15 unit /mg protein, while the activity was 0.15-0.25 unit /mg protein under PEG-mediated WDS. Similarly, increased synthesis of total proline and phenolic content under PEG-mediated WDS prevent oxidative damage to cellular structures and maintain plant existence by managing osmotic balance, preventing electrolyte leakage, and lowering concentrations of reactive oxygen species (ROS). The cumulative effect of morphological, physiological, and biochemical parameters under PEG-mediated WDS influence corm yield. Corm yield of taro genotypes decreased under PEG-mediated WDS compared with control. The reduction in corm yield varied between 15 and 16.2% in tolerant genotypes, 20.3% and 21.5% in moderately tolerant genotypes, and up to 41.4% in susceptible genotypes. Taro genotypes tolerant to PEG-mediated WDS exhibited early sprouting of cormel tip explants, lower reduction in shoot and root length, leaf area, CSI, RWC, g_s, P_N, stable intercellular CO_2 (*Ci*), TSS, RS, soluble protein content, corm yield and lower rate of increase in stomatal resistance, lower rate of decrease in transpiration rate (*E*), higher proline, phenol content, SOD and GPX activities compared to WDS free plants. The reduction in corm yield was significantly and positively correlated with leaf area, CSI, P_N, g_s, *E*, protein, TSS, RS, and inversely correlated with SOD.

Chowdhury et al., (2010) evaluated four cultivars of swamp taro *viz.*, BCST-4, BCST-15, BCST-23 and a local collection, Erasma local and one cormel forming taro cultivar, Cooch Bihar, under swampy conditions in low lying areas. Maintenance of greater leaf area, leaf chlorophyll, root nitrate reductase activity in post submergence period suggested the suitability of BCST- 15 for cultivation in low lying, flood-prone areas. Decrease in soil moisture drastically reduced leaf area, leaf longevity, stomatal opening and dry matter production (Ravi and Chowdhury, 1993a; Ravi and Chowdhury, 1991) and corm yield in taro (Ravi and Chowdhury, 1996). Hence optimum supply of water is a critical input throughout the growth period of taro.

Twenty-five percent of soil moisture saturation adversely affected the growth and corm yield of *eddoe* type of taro (Ravi and Chowdhury 1991). Corm bulking stage of taro occurs during the 4^{th}, $5^{th}$and 6^{th} month period which is considered as the most critical period of water deficit stress. The effect of water deficit stress on seven taro genotypes was studied to understand the biochemical, physiological variations and tolerance mechanisms by More et al., (2019). Highly significant differences ($P<0.001$) were observed for all varieties/genotypes and parameters selected for the study. As a consequence of water deficit stress, leaf proline, chlorophyll leaf protein content showed significant alteration in stressed plants. As a defensive mechanism, proline content (Irrigated: 66-90 μg/g; water deficit stress: 200-358 μg/g) increases in plants subjected to WDS. Under WDS conditions, significantly higher chlorophyll a (1.23 mg/g), chlorophyll b (0.37 mg/g), total chlorophyll (1.6 mg/g) and carotenoid content (0.31 mg/g) were recorded in genotype Jankri, whereas, significantly higher protein (1.10 mg/g) and proline content (358 mg/g) were found in Sree Reshmi and Tamarakannan, respectively. Significantly higher relative water content (67.15%) was exhibited by Telia genotype, whereas, Sree Kiran variety was more drought-tolerant owing to higher chlorophyll stability index (53.67%) and membrane stability index (45%). Taro plants grown under 25% soil moisture saturation showed greater reduction in relative water content (RWC), total chlorophyll, sugar content and membrane stability in leaves. Accumulation of greater amount of proline in leaves under 25% soil moisture than under 50% and 100% soil moisture saturation indicated that plants under 25% soil moisture have undergone maximum stress than those under 50% and 100% soil moisture saturation (Ravi and Chowdhury, 1991,1993b).

Water requirement

Taros are primarily adapted to moist environments but can be grown under a wide range of conditions, ranging from paddy culture to dry upland conditions under irrigation. Taro can be grown in upland areas where the rainfall is about 175 cm provided it is evenly distributed throughout the growing period. In upland culture of taro, it is important to ensure continuous availability of water. Wherever rainfall is irregular, irrigation facilities must be arranged. Taro requires about 450 g of water for one gram dry matter production (Mandal, 1993).

Taro performs well under moist situations. When grown under dry, upland areas with less than 175 cm of rain, supplementary irrigation is necessary to provide sufficient water to maintain the rhizosphere soil near the field capacity for optimum vegetative growth and leaf development; and the adoption of furrow and sprinkler irrigation methods have proved satisfactory (FAO, 2005). In India, the *Kharif* crop is grown under rainfed conditions, but if the rainfall is not regular, protective irrigation should be given for high yield and profit (Nedunchezhiyan and Sahoo, 2019). Summer crops require more frequent irrigation at 10 days intervals (Singh and Samajdar, 2014). Under upland conditions, taro needs continuous irrigation up to 24 weeks after planting @ 75% of cumulative pan evaporation (IW/CPE ratio of 0.75) for producing optimum cormel yield as well as total yield

(ICAR-CTCRI, 2019). Water requirement of upland taro was worked out to be 2.9 to 3.3 mm per day for producing optimum cormel yield and water productivity ranged from 2.6 to 4.5 kg/m^3 under different irrigation levels (ICAR-CTCRI, 2019). Irrigation throughout the growing season increases yield of corms and cormels. Summer crops required more frequent irrigation at 10 days intervals (Sarnaik and Peter, 1977; Nedunchezhiyan and Sahoo, 2019). About 5-8 irrigations are required for maximum yield of cormels under summer conditions for Bihar and 8-10 for Andhra Pradesh (Nedunchezhiyan and Sahoo, 2019).

Arsenic (As) in irrigation water

In West Bengal, taro is grown and irrigated with groundwater contaminated with arsenic ranging from 0.10 to 0.29 ml/L. The soils are also contaminated with arsenic ranging from 9.08 to 9.24 mg/kg. Under such conditions, at the early crop growth period (2 months after planting), arsenic accumulation in the different plant parts was in the order of leaf > petiole > cormel irrespective of cultivars (Kundu et al., 2011). At maturity (6 to7 months after planting), the degree of arsenic accumulation in different plant parts was still in the same order as in the earlier periods and differed significantly among the cultivars. The cultivar Satamukhi accumulated maximum (0.74 mg/kg) amount of arsenic in its cormels (Kundu et al., 2011). The cultivar Muktakeshi had the least arsenic in its cormel (0.27 mg/kg) followed by the cultivar Telia (0.28 mg/kg). Among the cultivars tested Telia and Muktakeshi registered higher cormel yields of 931 and 926 g/plant, respectively.

Cropping systems

Taro is a popular crop in eastern India. It is grown both under upland and lowland conditions. It is grown in *Kharif*, *rabi* and summer seasons. Following cropping systems are followed in Odisha, West Bengal, Madhya Pradesh, Uttar Pradesh and Andhra Pradesh (Nedunchezhiyan and Laxminarayana 2006; and Srinivas et al., 2012).

Odisha

Taro (sole crop) (upland and lowland) (*kharif*)

Taro + turmeric or ginger (upland) (*kharif*)

Taro (dasheen type) + greater yam in black cotton soil (upland) (*kharif*)

Taro + maize (*rabi*)

Taro (*dasheen*) (sole crop during summer)

Rice (*kharif*) - taro (*rabi*) (lowland)

Taro (*kharif*) - vegetables (*rabi*) (low land)

West Bengal

Taro (latikachu) + edible jute or amaranth or cabbage or onion or cauliflower

Taro (*kharif*) - sweet potato (*rabi*) - moong (summer)

Taro (*kharif*) - vegetables (*rabi*) - moong (summer)

Madhya Pradesh

Taro (Sole crop) (*kharif*)

Uttar Pradesh

Taro + ginger or turmeric (kharif)

Andhra Pradesh

Taro (Sole crop) (*kharif*)

Taro + greater yam (*kharif*)

In taro, maize, red gram (pigeon pea), turmeric and ginger are grown as intercrop to augment income. Experiment conducted on additional series by introducing intercrop (cowpea/ French bean/ turmeric/ ginger) one or two rows in between two rows of taro revealed that maximum net assimilation rate (0.003 g/m^2/day) was observed in taro with one row of turmeric as intercrop at 60-90 days after planting (Thokchom et al., 2018). However, among the intercropped treatments maximum taro yield (19.2 t/ha) was recorded in combination with single row of cowpea. The reduction in taro yield is compensated by intercrop yield in intercropping. Higher taro equivalent yield of 46.3 and 32.3 t/ha was obtained when taro was intercropped with ginger in double (1:2) and single (1:1) rows in additive series compared to sole taro yield of 23.9 t/ha (Thokchom et al., 2016). Field experiment conducted on replacement series at Bhubaneswar, India revealed that intercropping five rows of taro with one or two rows of maize or pigeonpea was biologically efficient system and taro + pigeon pea (5:1) system resulted in high B: C ratio of 2.35 (ICAR-CTCRI, 2019). In replacement series, sole taro crop produced higher yield, gross and net returns (ICAR-CTCRI, 2019). Among taro + green gram, taro + black gram intercropping systems taro produced 6 t/ha cormels in sole cropping and 5.7 t/ha in intercropping whereas, green gram produced 11.2 t/ha and black gram produced 10.4 t/ha (ICAR-CTCRI 2018). In taro+maize, and taro + redgram, intercropping systems, taro produced 16.6 t/ha in sole cropping and 15.6 t/ha in intercropping. Here, redgram and maize produced cormel equivalent yields of 7.5 and 4.9 t/ha respectively when intercropped with taro. Taro as sole cropping resulted in highest gross income and net income of respectively and B:C ratio of 2.24. Intercropping redgram and maize with taro in 1 or 2:5 ratio resulted in both gross and net income on par, had high land equivalent ratios (LER) as well as area time equivalent ratios (ATER) >1 and high B: C ratio of 2.35 and 2.23 respectively (ICAR-CTCRI, 2019).

Taro generally takes more time for sprouting (15-20 days). During this period, interspaces of taro may be utilized for production of short-duration leaf vegetables like red and green amaranth, spinach, fenugreek, coriander and mustard as these leafy vegetables require only 25-35 days for attaining harvestable stage. One row of above leafy vegetables sown in between two rows of taro as additional series (1:1) revealed that mustard matures (25 days) early among intercrops. However, higher taro equivalent yield was noticed with fenugreek and spinach in the descending order (Shankar et al., 2016). This was due to higher yields of intercrops as well as lack of intercrop effect on taro yield. Taro + fenugreek (1:1) and taro + spinach (1:1) intercropping (additive series) resulted in higher B: C ratio of 4.96 and 4.61, respectively (Shankar et al., 2016).

Taro intercropped in coconut garden wherein light infiltration is 50%, produced higher cormel yield and net return with the nutrient uptake and soil test based application of $N:P_2O_5:K_2O$ dose of 105:13:62 kg/ha (Geetha et al., 2005).

2.18. Swamp taro production

Swamp taro is a popular food crop among the lower-middle and lower-class people of North Bengal because of its low cost and abundant availability during rainy season when other vegetables become costly (Sivakumar et al., 2005). The swamp taro produces stolons/ runners from its modified stem. Initially these stolons runners are used for consumption and later used to produce plantlets for seed/ propagation. Various landraces of swamp taro namely *shola kachu*, *lati kachu*, *jal kachu*, and *kala kachu* are commonly cultivated. There are three types of swamp taro production systems based on the type of cultivation, irrigation and cropping pattern (Sivakumar et al., 2005). The salient characteristics of the production systems are given in Table 4. Among these systems, the rainfed monocropping swamp taro system is found in Dinhata block of Cooch Behar district whereas irrigated mono and intercropping are followed in Dinhata and Cooch Behar blocks of Cooch Behar district and Minaguri block of Jalpaiguri district. Under commercial cultivation swamp taro is grown as irrigated monocrop whereas intercropping of Amaranthus, cabbage, cauliflower and edible jute is being followed in smallholdings to meet the household food needs.

Table 4. Characteristics of swamp taro production systems in the Northern West Bengal India

Particulars	Lowland		Upland
	Rainfed monocrop	**Irrigated monocrop**	**Irrigated intercrop**
Nursery management	Stolons obtained from self-sown or waste of previous crop	Stolons obtained from nurseries were maintained during July-December. No fertilizer is applied in nursery.	Stolons obtained from nurseries were maintained during July-December. No fertilizer is applied in nursery.
Land preparation	Only cleaning of land due to permanent waterlogging	Tractor plowing	Plowing with bullock driven wooden plough
Planting time	November	November	December
Planting material	Sprouted stolons are planted in waterlogged field	Sprouted stolons are transplanted	Sprouted stolons are transplanted
Spacing	60 cm x 60 cm	60 cm x 45 cm	60 cm x 60 cm
Manures and fertilizers	FYM 2.5 t/ha as basal. No chemical fertilizer is applied.	FYM 5.2 t/ha applied as basal and top dressing at 40 and 60 days after planting (DAP).	FYM 0.5-0.75 t/ha, urea 100-125 kg/ha, DAP 200 kg/ha and potash 175 kg/ha as basal. Urea 75 kg/ha and MOP 115 kg/ha as top dressing at 120 DAP.
Irrigation	Rainfed	Irrigation once in a fortnight from March onwards.	Irrigation once in a fortnight from March onwards.
Intercultural operation	Hand weeding and earthing up at 150 DAP, and hand weeding and twisting of suckers at 180 DAP.	Weeding and earthing up with hand-drawn plough 150 DAP and hand weeding and twisting of suckers at 180 DAP.	Hand weeding and earthing up at 120 DAP.
Pest and disease management	Root grub infestation causes	Leaf folder infestation was	Root grub infestation causes

Particulars	Lowland		Upland
	Rainfed monocrop	Irrigated monocrop	Irrigated intercrop
	yield reduction up to 20%.	found during 150-180 DAP.	yield reduction up to 10-15%.
Yield	Stolons: 3.8 t/ha Petioles: 16 t/ha	Stolons: 4-6 t/ha Petioles: 40-60 t/ha	Stolons: 3.6-4 t/ha Petioles: 16-20 t/ha
Intercropping	Not found	Not found	Planting of leaf amaranth, onion, garlic and cabbage during January-February and edible jute during march-April. All intercrops are harvested before June.
Special character	Subsistence farming	Commercial cultivation	Subsistence farming

Source: (Sivakumar et al., 2005)

Taro in integrated farming system

Taro dominates in traditional farming systems and is an integral part of social rituals, a crop of great social importance especially in North-eastern India. Tuber crops-based integrated farming system is envisaged to enhance food and nutritional security of the farmers, to increase farm family income, to improve the livelihood of the farmers, and to create and distribute the employment opportunities throughout the year. Tuber crops-based farming system includes growing tuber crops with other seasonal, horticultural and silvicultural crops either in mixed/intercropping or sequential cropping; utilization of tubers and leaves in animal production either fresh or processed form. Among tuber crops, taro is capable to utilize available resources more efficiently especially partial sunlight. Great flexibility in planting and harvesting is additional character of this crop which is optly suitable to include in any farming system. In Odisha, under tuber crops based integrated farming systems, taro yielded 11.7-16.5 t/ha with the net return of US$ 2,507-3,219/ha (Rs.183,000 to 2,35,000/ha) with B:C ratio of 2.91-4.67 (Nedunchezhiyan et al., 2018b). In Chhattisgarh, under tuber crops-based integrated farming systems, taro yielded 24.2 t/ha with the net return of US$ 4,344/ha (Rs. 317,100/ha) with B:C ratio of 2.89 (Nedunchezhiyan et al., 2018b). In Jharkhand, under tuber crops-based integrated farming systems, taro yielded 13.6 t/ha with the net return of US$ 3,808/ha (Rs. 277,966/ha) with B:C ratio of 2.92 (Nedunchezhiyan et al., 2018b). At Harminder Bay in Little Andaman, under tuber crops-based farming system, taro gave higher net return US$ 4,132/ha (Rs. 301,666/ha) and B: C (1.48) ratio among tuber crops (Damodaran et al., 2016). Taro produced cormel yield of 11.3 t/ha in tuber crops based integrated farming system under rainfed ecosystem in Assam (Saud et al., 2016). Inclusion of taro along with other tuber crops in the integrated farming system will provide additional income to tribal farmers in hilly areas of Manipur (Devi and Singh, 2016).

Harvesting and yield

Maturity is indicated by leaves beginning to turn yellow followed by drying up of leaves. The crop matures 5-7 months after planting depending upon the type and varieties (Sarnaik and Peter, 1977; Mohankumar and Sadanandan, 1989; Nedunchezhiyan and Sahoo, 2019). However, under moist soil conditions, the crop will remain green therefore, water supply should be withdrawn after five to six months to allow the crop to dry. However, harvesting could be done at the convenience of the farmers as no serious deterioration has been reported if the harvest is delayed over a few weeks. Delaying the harvesting of taro after maturity may cause rotting of cormels and corms. Occasionally, roots of weeds may damage corms and cormels by penetrating inside making them unfit for consumption. Twisting of fresh suckers around the mother plant at its base, followed by earthing up one month before harvest helps in proper bulking of corm and cormels. Harvesting is done by digging out the corms and cormels. The mother corms and cormels are separated before marketing. In *dasheen* taro mother corms are marketed while cormels are marketed in *eddoe* type.

In swamp taro, the tender stolons are harvested by selecting stolons not more than 45-50 cm length. Harvesting of stolons between 5 and 7 months after planting (MAP) resulted in 6 t/ha (Roy Chowdhury et al., 2006) yield, whereas, harvesting of stolons between 4 and 10 months after planting resulted in higher runner yield of 20 t/ha with BCST-15 variety (Chowdhury et al., 2012). The accession CAUST-2 produced maximum yield of stolons (195 g/plant) which was *at par* with the variety CAUST-1 (191g/plant) under Manipur conditions (Laishram, et al., 2019).

Post-harvest handling

Damage to corms/cormels should be avoided while harvesting. The damaged corms/cormels should be separated from the marketing lot and consumed within 2-3 days. The tubers selected for marketing purposes should be spread on ground under shade for a day and the soil adhering to the tubers should be removed before packing. Tubers should not be packed in airtight containers. Packing in jute bags or baskets prevents rotting during transportation and storage.

Storage and dormancy

Healthy, disease and injury-free uniform-sized cormel should be selected and stored in a cool place at least for 3 months before planting. One tonne cormel is enough for planting a hectare crop. Sometimes, mother corms are also used as planting material. There is no yield difference in planting mother corm or cormel as seed material. In terms of price, mother corm is relatively cheaper than cormel. However, storability of mother corm is a constraint. Mother corm is also bigger in size weighing 200-400 g hence, needs huge volume of storage structure for storing. Mother corms have shorter shelf-life during storage starts rotting after 15 days due to high moisture content, if ventilation was not properly maintained. Dormancy period of mother corm (30-45 days) is relatively lesser than cormels (60-90 days). Soaking with morphactin or chlorflurenol at 1000 ppm and coumarin at 100/1000 ppm significantly delayed sprouting and reduced the percent sprouting of taro corm (Agarwal and Kumar, 1979). Eddoe type of taro cormels treated with carbendazim (0.05%) or *Trichoderma viride* (0.5%) had prolonged shelf-life (145-149 days), lower sprouting (6-7%), rotting (9-10%) and moderate weight loss (15-17%) (Padma et al., 2011).

Traditional storage systems are mainly suited for short-term storage of three months. During storage, the farmers incur huge losses of seed materials due to moisture loss, rotting as well as early sprouting of cormels. Since taro is a small farm-holders crop, its poor keeping quality due to post-harvest losses affects the livelihood security of the farmers. In general, the farmers select healthy cormels from October to December and store them for 3-4 months in shady places for planting in the next season under Assam conditions (Alam et al., 2014). Poor storage conditions cause yield losses from 50 to 95% for a storage period of 2-5 months. The yield losses are caused mainly by weight loss, rotting, mealybug and other insect pests during storage. Besides, yield losses, corm/cormel viability are also reduced during storage (Modi, 2007).

Rotting of taro cormels during storage is a very serious factor limiting the quantity and quality of planting materials. Storing taro cormels for 90 days on ground (*kaccha* floor) resulted in highest rotting index (40%) and physiological loss (43.4%) in weight (Alam et al., 2014). However, pit storage with or without fungicide treatment was found effective. The taro cormels treated with *Trichoderma viride* and stored in pits lined with polythene sheet and containing moist sand were effective in decreasing the rotting index (19.4%) throughout the storage period. Treating taro cormels with *T. viride* helps to reduce cormel rot as well as leaf blight infection in the taro field (Misra et al., 2008).

During storage, the sugar content of taro cormels increased with progressive time as starch degraded. The reduction of starch with storage may be due to the hydrolysis of starch to sugar and finally into organic acids by a starch degradation enzyme alpha-amylase (Modi, 2007). Storage of taro cormels in pit lined with polythene sheet containing dry sand is an efficient low-cost mechanism wherein physiological loss in weight, rotting index and starch degradation were minimal and sprouting index was maximum (Alam et al., 2014).

Seed/ planting material production

Cormels and corms constitute the seed material of taro. The technology for raising the seed crop is similar to commercial cultivation. However, if the cormels and corms are to be used for seed purposes, the crop should be disease-free and fully mature. After harvesting, the cormels and corm should be cured for 10-15 days in a shaded place by spreading them in single layer. Damaged cormels and corms should be removed and uniform-sized corms and cormels stored in a shaded and ventilated place. Occasionally the cormels and corms should be examined and damaged ones removed. The seed cormels and corms can safely be stored for 3-4 months. After 2-3 months of storage, the tubers will start sprouting.

Seed certification standards for the production of quality planting materials

The general seed certification standards are basic and together with the following specific standards constitute the certification standards for taro (Muthuraj et al., 2016).

Land requirements

Land to be used for seed production of taro shall be free from volunteer plants. Avoid swampy, low lying and over shaded conditions. 2. Avoid taro residue and drainage from other taro fields.

Field inspection

A minimum of three inspections shall be made, the first and second inspection at 60 and 90 days after planting, respectively, and the third at 160 days after planting and before harvesting or at appropriate growth stage depending on the crop duration of the variety concerned to check isolation, off-types and other relevant factors.

Field standards

Seed fields shall provide minimum isolation distance of 5 meters for foundation seed and certified seed. The isolation distance should be maintained from fields of other varieties as well as fields of the same variety not conforming to varietal purity requirements for certification. The details of maximum permissible limits of off-types, pests, and disease for foundation seed and certified seed are given in Table 5.

Table 5. Maximum permissible limits of off-types, diseases and pests in foundation seed and certified taro seed plot.

Factor	Maximum permitted (%)*	
	Foundation	**Certified**
Off types	0.1	0.5
Plants showing symptoms of dasheen mosaic	0.5	1
Plants infected by *Phytophthora colocasiae* (Rac.) disease	None	None
Plants infected with scale insects and mealybugs	None	None

*Standards for Off-types shall be met at final inspection and for designated diseases and insects at each inspection.

Note: 1. All Off-types, diseased and insect-infested plants shall be rogued out along with corms, cormels and destroyed.

2. Gaps in the seed field shall not be more than 10.0%.

Seed standards

For foundation and certified classes, seed standards for seed corms are 4-6 cm x 2.5 cm to 3.5 cm with weight ranging between 20-40 g.

1. In a seed lot, corms/cormels not conforming to specific sizes of seed shall not exceed more than 5.0% (by number).
2. The seed material shall be reasonably clean, healthy, firm and shall conform to the characteristics of the variety. The corms/cormels not conforming to varietal characteristics shall not exceed 0.1% and 0.5% (by number) for foundation and certified seed classes respectively.
3. Cut, bruised, cracked corms/cormels of those or those damaged by insects (other than scale insects and mealybugs), slugs or worms shall not exceed more than 1.0% (by weight).

4. There should not be any visible symptoms of scale insects and mealybugs infestation on the corms/cormels for foundation seed and certified seed.

Micropropagation

Maintenance of germplasm in the field genebank demands not only greater resources, but also the germplasm is always at risk due to pest and disease infestation and other natural calamities. Application of plant tissue culture has been found very useful for rapid multiplication, safe exchange and conservation of germplasm of many vegetatively propagated crops. Micropropagation systems in taro have been developed that can be used for a wide range of cultivars. Furthermore, induction of *in vitro* storage organs is useful for conservation of germplasm of many vegetatively propagated root and tuber crops, for instance, potato, sweet potato, yams and tannia. Since somaclonal variations may occur in *vitro* cultures, it is important to ascertain the genetic fidelity of *in vitro* conserved germplasms. The protocol for *in vitro* regeneration of eddoe taro has been developed (Hussain and Tyagi, 2006; Bhagavan et al., 2013; Sahoo et al., 2006, 2018; ICAR-CTCRI, 2019).

Using shoot apices of 2-3 cm length as explants plantlets and *in vitro* corm formation was achieved on Murashige and Skoog's (MS) medium, containing 8-10% sucrose, 22 µMN6- benzyl aminopurine (BAP), 0.6 µ*M α*-naphthaleneacetic acid (NAA) and 0.8% agar, in *eddoe* taro. The corm forming cultures could be conserved up to 15 months at 25+2^{o}C. Shoot-forming cultures could last for only 6 months on MS medium, containing 3% sucrose + 2.2 µMBAP + 0.6 µM NAA + 0.8% agar. Plantlets with *in vitro*-formed corms showed 100% survival in the field and developed normal uniform corm-producing plants. Uniformity of tissue culture regenerated plants with corm was determined based on 12 qualitative and 10 quantitative morphological traits related to leaf, petiole, corm and root. Apart from morphological assessment, the genetic stability of the plants regenerated within *vitro* corms could be assessed by using two simple polymerase chain reaction (PCR)-based molecular marker techniques, i.e. random amplified polymorphic DNA (RAPD) and inter-simple sequence repeats (ISSR). A total of 13 RAPD primers (of 35 tested initially) and 6 ISSR primers gave 111 distinct bands in RAPD and 43 in ISSR, and exhibited uniform RAPD and ISSR banding patterns for plants with corms. This protocol for *in vitro* corm formation may cost-effectively be applied for conservation of taro germplasm along with maintaining the genetic stability and functionality of plants and for production of disease-free planting materials (Hussain and Tyagi, 2006).

Bhagavan et al., (2013) using apical shoot apices and auxiliary buds of 0.5 to 1.0 cm length from taro cormels achieved plantlets on Murashige and Skoog's (MS) medium, containing 3% sucrose, 5-20 μMN6- benzyl aminopurine (BAP)/2.5-10 μM kinetin and 0.7% agar, in *eddoe* type taro. The number of shoots per plant was more when shoot apices were used as explants compared to auxiliary buds. MS media supplemented with 20 μM BAP resulted in highest number of shoots/plantlets (2-11) from shoot apices as explant. One hundred percent root initiation was achieved within 5 days in half strength of MS basal media + 0.05% activated charcoal without any plant growth regulator. Well acclimatized plants at three months after hardening under polyhouse/green-house conditions could be successfully transplanted and established under field conditions.

Direct regeneration could be achieved from sprouts from *eddoe* taro corm in the MS medium supplemented with BAP alone and along with other growth regulators while indirect regeneration was recorded in medium with 2, 4-D along with TDZ and BAP. Highest number of shoots (3.5/explant) was recorded in medium with 4 mg/l BAP along with 1.0 mg/l NAA. Taro plants with well-developed shoot and roots were obtained in MS basal medium with 3.0 mg/l N6- Benzyl adenine (BA) (ICAR-CTCRI 2019). Sahoo et al., (2018) regenerated plantlets by culturing cormel tips as explants in MS media supplemented with plant growth regulators such as α–naphthalene acetic acid (NAA, 2.7 μM), 6-benzyl adenine (BA, 4.4 μM), and gibberellic acid (GA_3, 1.45 μM).

Growth characteristics

Taro plants have indeterminate growth habits. Therefore, they can continuously grow as long as the soil moisture is available. In taro, the corm initiation time, corm growth and total growth period vary widely depending on the cultivar and the agro-climatic conditions particularly soil moisture.
The physiological stages of *eddoe* taro are recognized to have four growth phases/stages (Mohankumar and Sadanandan, 1989).

The phase I; is the early establishment phase and lasts for about 4-6 weeks after planting during which both leaf (lamina +petiole) and mother corm dry matter decreased.

Phase II; represents early growth phase in which a slow increase in plant dry matter continues for about 6-13 weeks followed by grand growth period and the plants accumulate dry matter very rapidly reaching a peak during 5.5-6 months. Rapid increase in corm dry matter begins about 2 months after planting and the corm continues to develop.

Phase III; is a rapid or grand growth period in which the plants accumulate dry matter very rapidly at about 13-18 weeks.

Phase IV; is the bulking and maturity phase representing final growth period in which accumulation of dry matter in the corm and cormel continues while in tops continuous and rapid loss of dry matter occurs during 18-24 weeks.

During Phase-II, increase in leaf dry matter was more rapid than the increase in corm dry matter during this phase. Root dry matter increases steadily during Phase-I and Phase-II and reaches its peak at about 6th month. From about 6th month onwards, Phase-III can be recognized during which total plant dry matter declines. Leaf dry matter decreases very rapidly and levels off at very low values. The corm DM continuously increases up to 10-11.5 months. However, taro cultivars were found to produce significant corm yield in 5 months growth period in upland under rainfed conditions (Ravi and Chowdhury, 1996). In these cultivars, the leaf area continuously increased up to 4 months and decreased at 6th month due to decrease in soil moisture because of decrease in rainfall.

There was a decrease in leaf growth at later stages (6th month) in four cultivars of swamp taro, *viz*., BCST-4, BCST-15, BCST-23 and a local collection, Erasma local and one cormel forming taro cultivar, Cooch Bihar under swampy conditions in low lying areas due to decline in soil moisture because of decrease in rainfall. Maintenance of greater leaf area, leaf chlorophyll, root nitrate reductase activity in post submergence period suggested the suitability of BCST- 15 for cultivation in low-lying flood-prone areas (Chowdhury et al., 2010). In taro, the time of initiation of corm/cormels, corm growth and the total growth period varies widely depending upon the cultivar and the agro-climatic conditions, particularly soil moisture (Ravi, 2000).

Leaf growth and canopy development

The canopy development in taro is slow at initial stage. Sprouting of the corm/cormels could be noticed during third week after planting. The canopy coverage of the plant increases with age due to increase in number and size of the leaves and reaches full cover between 2-3 to 5 months after planting depending upon the genotype and cultural conditions. A rapid and reliable linear measurement method for estimating the leaf area of intact leaves of taro was developed by Biradar et al., (1978).

The equation Y=0.917 (P)

(P- product of length and breadth of leaf).

In taro, leaf area is closely related to yield. Significantly, strong positive correlations have been found between leaf area of leaf area index (LAT) and corm and cormel yield (Sharma, 1994). This suggests that plants with large canopies should be selected for higher yield. In many crops, maximum effective light interception and photosynthesis are reached when fully covered at an LAI of about three. And achieving full cover rapidly after planting and maintaining it throughout the growing season is important in maximizing yield. Taro crop grown under sprinkler irrigation, LAI of 2.8 was optimum, whereas with flooding com yield increased with increasing LAI up to 3.0 and with furrow irrigation, the optimum LAI ranged from 4.5 to 6.5. However, under normal spacing and cultural practices the LAl of traditional cultivars of taro are much below the optimum during most of the growth period.

Leaf area of taro crop increased gradually between 20 and 30 days followed by a steady decline at 50th day in ten different taro genotypes under rainfed conditions. Leaf area development per unit weight of dry matter accumulation per plant LAR significantly differed among genotypes at different stages of crop growth. The leaf area ratio (LAR) increased from 60th day onwards showing its peak at 90th day, followed by a gradual decrease at final stage of crop growth. The intervarieta1 correlation of different physiological parameters suggested a significant positive correlation of LAI with LAR and LAD while NAR and LAI showed non-significant negative correlation (Roychowdhury, 1995). High leaf area index associated with high dry matter production are the two important physiological parameters attributed for better yield in *eddoe* type taro.

LAI in taro crop correlated positively and significantly with LAD (r = 701) and corm yield/ha (r = 772), but correlated inversely and insignificantly with NAR (350) and RGR (-227) when the plants were raised with three levels of nitrogen (N) *viz.*, control (0kg N/ha), 100 kg N/ha and 200 kg N/ha with three spacings; 45 cm x 30 cm (Si) 45 cm x 45 cm (S) and 45 cm x 60 cm (Sz). The increase in LAI caused sufficient shade to the lower leaves beyond the compensation point, which was ultimately responsible for the reduction in NAR and growth rates (Nigam and Choubay, 1990). The detrimental influence of additional leaves below the compensation point depended mainly upon the respiration rate of such leaves. Similarly the crop growth rate (CGR) and leaf area ratio (LAR) increased linearly with LAI. All linear regressions between growth physiological parameters and yield were significant. With an increase in the magnitude of LAI, LAR and NAR beyond a certain limit, the economic productivity (yield) of taro decreases proportionately. The negative regression coefficients for LAI, LAR and NAR were 228.5, 25.0 and 6691.6 respectively. However, a positive regression coefficient of 11.84 for leaf weight ratio (LWR) with corm yield indicated the distribution of dry matter in the sink (corm). In a study involving ten morphologically contrasting *eddoe* taro cultivars (C1-106, C1-154, C1-149, C-266, Telia, Chiruli, Jankdi, Barandi, Aiginia and Muktakeshi). LAI had a significant positive correlation with LAR (r = 0.65*) and LAD (r = 0.78*). The NAR showed a highly positive, significant correlation (r = 0.68*) with CGR. The negative but insignificant correlation between NAR and LAI (r = -0.19) is attributed to an effect of mutual leaf shading particularly in cultivars with broader leaves. The LAI and CGR showed a significant positive correlation (r = 0.64* and 0.67* respectively) with corm/cormel yield. LAD showed a high but insignificant correlation with corm/cormel yield (Roy Chowdhury et al., 2000)

Taro has shallow root system and majority of the roots are confined to a lateral spread of 40 cm and a depth of 9 cm in the soil (Mohankumar and Sadanandan, 1990). Rooting patterns in taro at different growth phases are distinctively vary. During the early establishment phase on average there are 40-50 roots per plant. Majority of the roots at this stage are confined to a lateral distance of 0-40 and a depth of 5-8 cm in the soil. Maximum root production and activity occur during the grand growth phase. A greater portion of the roots at this stage is seen within a lateral spread of 0-30 cm and to a depth of 2-8 cm. The root number ranges from 125-200 per plant (Mohankumar and Sadanandan, 1990). At maturity, the root mass decreases to a depth of 2 - 5 cm. In taro vegetative growth increases progressively up to 120 days and there- after starts to decline whereas the tuber weight continues to increase from 60th day after planting till harvest, that is, 150 days after planting.

Response to shade

In general, taro is tolerant to shade conditions. Six morphotypes of taro when raised under artificial shade conditions using shade, bower (*pandals*) erected on wooden frames and covered with unplaited coconut fronds achieving in 0, 25, 50 and 75% shade did not result in significant effect on corm yield, cormel yield and harvest index, there was variation in all these parameters among the morphotypes (Tajuddin, 1992). Diurnal cycle of chlorophyll fluorescence parameters was studied in swamp taro grown in marshy land under sun and shaded conditions. Leaves under sun-light maintained higher electron transport rate (ETR) and steady-state to initial fluorescence ratio (F_s/F_0) than shaded leaves. Despite lower ETR, higher photochemical quenching (PQ), and effective quantum yield of photosystem 2 (Φ_{PS2}) were evident in shade plants compared to plants exposed to higher irradiance. ETR increased linearly with increase in irradiance more under low irradiance ($r^2 = 0.84$) compared to higher irradiance ($r^2 = 0.62$). The maximum quantum yield of PSII (F_v/F_m) did not differ much in sun and shade leaves except midday when excess light energy absorbed by plants under sun was thermally dissipated. Hence swamp taro plants adopted different strategies to utilize radiation under different irradiances. At higher irradiance, there was faster decline in proportion of open PSII centers (PQ) and excess light energy was dissipated through non-photochemical quenching (NPQ). Under shade, absorbed energy was effectively utilized resulting in higher Φ_{PS2} (Chowdhury et al., 2009b). Starch content of tubers increased with shading whereas oxalic acid content remains unaffected in corms.

Photosynthesis and dry matter production

Taro is a C_3 photosynthesis plant. Stomatal opening both on the adaxial and abaxial leaves of taro plants exhibited diurnal rhythm with a steady increase from 06.00 h to 09.00 h followed by a decline between 09.00 h to 13.00 h and a rise in the afternoon between 13.00 h to 15.00 h (Ravi and Roy Chowdhury 1993b). However, the effect of such diurnal changes in stomatal opening on photosynthetic rate of taro is not known. Net photosynthetic rate of individual plants varies between 22.36 to 28.52 μmol $CO_2/m^2/sec$ in field-grown taro plants (Ravi et al., 2019). Although differences in the total chlorophyll content in the leaves of taro genotypes were statistically significant, no definite correlation of P_n with the total chlorophyll content was observed (Ravi et al., 2019). Photosynthetic efficiency of field grown five *eddoe* taro cultivars (*viz*., Sree Pallavi, Muktakesi, Jhankri, Telia and Topi) and four dasheen type of taro genotypes (*viz*., NM/2017-1, NM/2017-2, NM/2017-3 and VHAK/2017-4) were evaluated by short term (10 min) exposure to various CO_2 concentrations *viz*., 400, 600, 800, 1000 ppm at 30°C and 1500 μmol/m²/h (Ravi et al., 2019). Net photosynthetic rate (Pn) steadily increased at elevated CO_2 (eCO_2) concentrations between 400 ppm and 1000 ppm in the leaves of all the nine taro genotypes. The genotypes had 61.80 – 113.3% hike in Pn at eCO_2 (1000 ppm) as compared to ambient CO_2 (400 ppm). However, the percent of increment in Pn at eCO_2 for every 200 ppm between 400 to1000 ppm significantly declined (4.4-18.4%) at 1000 ppm CO_2. Similarly, g_s altered significantly across taro genotypes ($P > 0.001$) and CO_2 concentrations ($P > 0.001$). The Ci steadily increased at eCO_2 concentrations between 400 ppm and 1000 ppm. Superior performance in terms of higher P_n was observed in Muktakeshi, Sree Pallavi and Telia genotypes.

In taro, corm bulking rate increased with advancement of age up to 115 days and decreased thereafter towards maturity due to reduced number of functional leaves and total leaf 1996 area (Narzary, 1996). Dry matter production keeps increasing to about 5 months after planting (Mohankumar and Sadanandan, 1989). The corm bulking rate varied among different cultivars of taro indicating a genotypic control over the process. However, the combination of higher bulking rate and prolonged leaf area produced the highest com bulking at harvest. N significantly affected the cormel bulking rate at 80 kg N/ha with 0.90 g/plant/day and declined to 0.88 g/plant/day at 120 kg N/ha. K increased the cormel bulking rate with increasing K level. The cormel bulking rate at 50 kg K_2O/ha was 0.77 g/plant/day which in turn increased to 0.85 and 0.88 g/plant/day at 100 and 150 kg K_2O/ha. CGR was maximum at 80 kg N/ha (3.67 g/m^2/day) and declined at 120 kg N/ha (3.57g/m^2/day). Effect of P and K was insignificant on CGR (Mohan Kumar 1989). The most important character contributing to yield is the number of cormels per plant and genotypic correlation was higher than phenotypic or environmental effects (Pillai et al., 1995). Path coefficient analysis of five traits *viz*., number of leaves, number of corms, weight of corms, number of cormels per plant and mean weight of cormels on yield revealed that the number of cormels per plant had maximum direct effect on yield followed by mean cormel weight. Therefore, yield in taro is mainly determined by the number of cormels per plant. The highest values of phenotypic coefficient of variation (35.73%) as well as genotypic coefficient of variation (33.65%) were reported for yield followed by weight of cormels per plant (Kumar et al., 1995). Number of suckers/tillers and cormels per plant had high correlation with cormel yield (Sarkar et al., 1996). Thus, more emphasis should be given to these traits while selecting for yield.

Management of Pests

In India, taro is reported to be infested by sucking pests such as aphids (*Aphis gossypii* Glover and *Pentalonia nigronervosa* Coquerel), whitefly (*Bemisia tabaci* (Gennadius), banana lacewing bug (*Stephanitis typicus* Distant), leaf thrips (*Thrips* sp. Haliday) and mealybug (*Formicococcus polysperes* Williams), defoliators (Tobacco caterpillar, *Spodoptera litura* Fabricius), silver striped hawk moth (*Hippotion celerio* Linnaeus) and white spotted flea beetle (*Monolepta signata* Olivier) and borer pest (Taro corm borer, *Haplosonix chalybaeus* Hope). Timely intervention with suitable management strategies is very effective against these pests.

Sucking pests

Cotton/ Melon aphid, *Aphis gossypii* Glover (Hemiptera: Aphididae)

Cotton aphids both nymphs and adults feed on the underside of leaves, or growing tip of veins, sucking nutrients from the plant. The foliage may become chlorotic, turn yellowish and die prematurely. Their feeding also causes a great deal of distortion and leaf curling, hindering photosynthetic capacity of the plant. Indirect damage is caused by the accumulation of honeydew produced by the aphids. Honeydew serves as a substrate for sooty molds, which blacken the leaves, reducing photosynthesis and plant vigor. Aphids are vectors of dasheen mosaic poty virus (Singh et al., 2008; Parvatha Reddy, 2015).

Banana aphid, *Pentalonia nigronervosa* Coquerel (Hemiptera: Aphididae)

Banana aphids are the pest of taro mainly found in the lower region of the leaf along midrib. Damage is caused by both nymphs and adults by sucking cell sap. Black shooty molds develop on honeydew secreted by aphids on leaves. Dry condition favors population flair up (Sushil et al., n.d.)

Management

- Avoid planting taro closer to alternate hosts such as melon, cotton, cucumber, or other cucurbits.
- Provide hedges to limit movements of aphids from one crop to another and to encourage natural enemies.
- Sprinkler irrigation or sustained rain can reduce infestation.
- Control ants in the field, as these will disrupt natural enemy activities.
- Destruction of infested leaves after harvesting
- *Predators*: Several aphidophagous predators observed on taro are coccinellids (*Menochilus sexmaculatus*, *Verania discolor*, *V. inops*, and *Pseudospidimerus circumflexus*) and syrphid (*Ischiodon scutellaris*). The predation is higher during larval stage, while it is less in adult stage. Among aphidophagous predators, *I. scutellaris* is a voracious feeder. Coccinellid *Scymnus latemaculatus* feeds on aphids.
- *Parasitoids*: Four species of parasitoids *Aphelinus mali*, *Aphelinus* sp., *Coccophagus cowperi* (Aphelinidae), and *Aphidencyrtus aphidivorus* (Encyrtidae) are active on *Aphis gossypii* in fields of taro, tania, and elephant foot yam.
- Treatment with Neem oil / Neem based formulation (7 ml/L), Imidacloprid 17.8 SL (0.3 ml/L) (Sunitha et al., 2020)

Whitefly, *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae)

Adults are soft-bodied, moth-like fly, yellowish dusted with white waxy powder and 1 to 1.5 mm in length. The females mostly lay eggs near the veins on the underside of leaves. They prefer hairy leaf surfaces to lay more eggs. Upon hatching, the first nymph moves on the leaf surface to locate a suitable feeding site. The wings are covered with powdery wax and the body is light yellow in color. Both the adults and nymphs suck the plant sap and reduce the vigor of the plant. When the populations are high, they secrete large quantities of honeydew, which favors the growth of sooty mold (Sushil et al., n.d.).

Management

Several potential parasitoids have been reported suppressing its population. Among them, *Encarcia* sp. and *Erectmocerus* sp. are very common in India. Although chemical pesticides are in use to manage the pest, this has been highly discouraged due to an array of reasons, including the deterioration of the natural enemies. The most feasible method for the management of whitefly is proper field sanitation and cultivation of resistant varieties. Removal of crop residues and rouging of infected plants also check the risk of carryover population. Other strategies can be set up yellow sticky trap, Install sticky cum light trap and operate between 4 to 6 am to attract adults. Insecticide Imidacloprid 17.8 SL @ 1ml/3l is effective in controlling this pest (Harish, 2019).

Mealybug, *Formicococcus polysperes* Williams (Hemiptera: Pseudococcidae)

The mealybug *Formicococcus polysperes* Williams was reported for the first time attacking rhizomes of taro from Nagaland, India. In initial infestation, the tender rhizomes were observed to be covered with whitish powdery mass of mealybugs. In severe infestation, the entire underground portions of the plant were covered with mealybugs along with the black sooty mould in patches on plant parts. The infected plants showed symptoms of yellowing and withering of leaves accompanied by underdeveloped rhizomes which eventually dried prematurely. Results on survey of fields and a nearby storage facility revealed up to 52% crop loss due to its infestation. On taro, mealybugs occur on the abaxial surface of the leaves, on and between the petioles, and on the roots and corms. On the roots, they occur as cotton-like masses, containing males and females, which are sometimes difficult to see clearly with the naked eye. Mealybugs have a long feeding tube that is used to pierce plant parts and suck the sap-in and doing so, causes a variety of symptoms. Direct feeding results in distorted foliage, yellowing, stunting, and wilting; indirectly, mealybugs cause a build-up of sooty mold fungi, which grows on the honeydew excreted as they feed. They also transmit viruses. In these ways, mealybugs are similar to aphids. On taro, mealybugs rarely harm the plants or promote sooty mold growth.

Management

1. Burn the severely infested plants.

2. Use a mixture of neem oil and soap solution for spraying. Preparation of spray solution: Add 20 ml of neem oil and 2-5 ml of soap solution in a plastic bucket and makeup to one liter. Vigorously shake the solution till it looks milky white with foam. Spray the solution in mealybug infested taro field. Nozzle of the spray should be turned towards the lower side of the leaf and ensure full coverage by the spray fluid. A second spray after 15days may ensure the death of residual population.

3. Use of CTCRI developed bioformulations *'Shreya'* (7ml/l) followed by *'Nanma'* (7ml/l) after one week.

4. Spraying synthetic insecticides may be done only if needed. There is number of natural enemies in the field to check the population of mealybugs, but the indiscriminate use of chemical insecticides will adversely affect its natural enemies and pave the way for pest resurgence. Insecticides like Imidacloprid 17.8 SL- @ 1ml/3l; Profenophos 50 EC- @ 2ml/l; Chlopyriphos 20 EC- @ 4ml/l; Dimthoate 30 EC- @ 2 ml/l are reported to be effective against mealybugs (Harish, 2019).

Leaf thrips, *Thrips* sp. Haliday (Thysanoptera: Thripidae)

Thrips hatch from an egg and develop through two actively feeding larval stages and two non-feeding stages, the prepupa and pupa, before becoming an adult. Females of most plant-feeding species lay their elongate, cylindrical to kidney-shaped eggs on or into leaves, buds, or other locations where larvae feed. When the weather is warm, the life cycle from egg to adult may be completed in as short a time as 2 weeks. Thrips feeding on base of leaves, affect plants' appearance with morphological deformity (Sushil et al., n.d.).

Banana lacewing bug, *Stephanitis* typicus Distant (Hemiptera: Tingidae)

Banana lace bug is also the pest of taro mainly feed on leaves. Females insert tiny, oblong eggs in leaf tissue and cover them with dark excrement. Lace bugs can overwinter as eggs in leaves of taro. All life stages can be present throughout the year in leaves and petiole of leaves. Adults and nymphs feed on the lower leaf surface, mostly in the region of the midrib. Feeding causes small white spots on the upper leaf surface opposite the feeding site;

chlorotic spots and dark excreta marks are left on the lower leaf surface. On taro leaves, the stylets are inserted through the stomata, rupturing cell walls, and terminating the phloem (Sushil et al., n.d.).

The management practices followed against mealybugs is found to be effective against thrips and lacewing bugs also.

Red spider mite *(Tetranychus urticae* Koch)

Red spider mites are tiny (0.3-0.5 mm), obnoxious, phytophagous pests during pre-summer months in swamp taro. In swamp taro the mites live in colonies on the ad-axial surface of leaves. A single colony may contain thousand individuals and can be visualized with a 10 x hand lens. During February-March, the mites appear suddenly and build up population fast. With the increasing infestation level, the mites extract huge amount of chlorophyll resulting in development of numerous non-photosynthetic necrotic spots which in turn coalesces and gives leaves a yellowish hue appearance. At this time, presence of moving and non-moving stages can be noticed on the ad-axial surface of leaves. Continuous feeding by the mites resulted in complete browning of leaves. The leaves become entangled with dust and webs which hamper the photosynthetic activity of plants resulting in stunted and unhealthy appearance. The severely infected leaves become dried and detached from the stem. The severely infected plants fail to produce quality stolons (Sarkar and Tarafdar, 2013). Mite population increased under prolonged dry weather conditions combined with low humidity (mean RH 73%), high temperature (32^{o}C maximum and 20^{o}C minimum) and longer sunshine hours (9.14 h) whereas high RH and rainfall adversely affected mite population. Spraying of acaricides such as Abamectin 1.8 EC, a GABA (γ-amino butyric acid) ergic pesticide @ 9 and 5 g a. i. per ha significantly reduced mite population (95-100%) at 24 h after application whereas spraying of Fenazaquin 10 EC 100 g a.i. per ha significantly reduced mite population (95%) at 24 h after application. Application of these acaricides had little effect on natural enemies. This was indicated by the negligible reduction on natural enemies such as *Amblyseius ovalis* (10-16%), *Agistemus hystrix* (11-14%), *Stethorus* sp. (2-13%), and *Chrysoperla carnea* (1-3%). These acaricides also had no phytotoxicity suggesting that these acaricides can be applied safely to control red spider mites in swamp taro (Sarkar and Tarafdar, 2013).

Defoliators

Tobacco caterpillar, *Spodoptera litura* Fabricius (Lepidoptera: Noctuidae)

It is an important polyphagous pest found in Asia and the Pacific. The early larval stages remain together at first, later radiating out from the egg mass, stripping the interveinal leaf surface and skeletonizing the leaves as they advance. Later stages eat all parts of the leaf, including the petioles (Bhattacharyya and Mandal, 2006). Older larvae are night feeders. Armyworms chew large areas of the leaf and, when numerous, can defoliate a crop. In such cases, the larvae migrate in large groups from one field to another in search of food (Parvatha Reddy, 2015). The population of the pest is as high as 63 caterpillars/leaf and can cause damages as 16 to 80% (Singh et al., 2008).

Management

1. Cultural methods: Most taro growers manually smash cluster caterpillars with their hands when infestations are light. Heavily infested leaves are removed and burned.

(a) Botanicals: Two round spraying of 5 % aqueous yam bean seed extract starting from 50 % flowering stage at 15 days interval was found effective against *Spodoptera litura*. Rotenol is the active ingredient in yam bean seed extract which is responsible for the control of pests.

2. Biological methods*:* Caterpillar eggs are parasitized by *Telenomus* sp. and *Chelonus* sp. (Hymenoptera) and larvae by *Apanteles* sp., *Euplectrus* sp., and *Zele* sp. and by the fly *Palexorista* sp. Chickens are reported to pick caterpillar larvae from taro leaves. Dipel (*Bacillus thuringiensis* sub-sp. *kurstaki*, Abbott Laboratories) has been used in the past against *S. litura*.

3. Chemical methods*:* Pesticides are seldom necessary. One application of malathion is recommended by the extension service to control heavy infestations.

Silver striped Hawk-moth, *Hippotion celerio* Linnaeus (Lepidoptera: Sphingidae)

Larvae may be green, yellowish-green or even brown. Small-to-large holes in the leaf margin are typical damage symptoms. The larvae, particularly during the later stages, feed voraciously, leading to severe defoliation; the leaves may be consumed down to ground level. The larvae also feed on young succulent stems and shoots and the newly sprouted shoots. Infested plants have large areas of leaf missing and the leaf appears ragged. The larvae can be found on the leaves during the day, often on the underside (Parvatha Reddy, 2015).

Management

1. Physical methods: The larvae are large and relatively easily seen; they can be picked off the plants by hand. In small taro plantings, this is the best means of control.

2. Chemical methods: Applications of chemical sprays may help control populations of hornworm. Present recommendations in the Pacific Island countries include Indoxacarb (e.g., Steward), Spinosad (e.g., Success), *Bt* (e.g., Delfin, Thuricide, Dipel), and Imidacloprid (e.g., Confidor, Mustang).

3. Biological methods: The caterpillars of hornworms are usually parasitized (6-10%) by a Hymenopteran *Charops hersei* under field conditions. *Hippotion* spp. caterpillars are also preyed upon by a wasp *Polistes* sp. under field conditions.

White-spotted flea beetle, *Monolepta* signata Olivier (Coleoptera: Chrysomelidae)

It is an important pest feeding on leaves of taro. Besides the feeding it also predisposes to sclerotium rot. The beetle lay minute eggs are laid in soil cracks around the base of the host plant. Minute worm-like larvae live in the soil and feed on small plant roots and root hairs. The hard forewings are black with two yellowish markings, one in front and the other behind the middle. Adults make large holes in leaves by feeding leaf tissues. Adults are conspicuous and commonly found on leaves. The grubs were preyed upon by *Eocanthecona furcellata* in field (Parvatha Reddy, 2015).

Borer pests

Corm-borer, *Haplosonyx /Aplosonyx chalybaeus* Hope (Coleoptera: Chrysomelidae)

The corm-borer (*Haplosonyx chalybaeus* Hope) is a regular and endemic pest causing 20-30% damage to the foliage and 80-90% to the corms, resulting in severe losses to the tribal farmers of North Eastern India. The pest occurs only in states adjoining Himalayan region (Sikkim and Meghalaya) and not in tropical regions of India (Swamy et al., 2002; Korada, 2012, 2013). Barwal, (1988) first identified *H. chalybaeus* on taro as a new record in Meghalaya. Later, the pest was also reported from several South Asian countries (Maddison, 1993). Infestations of *H. chalybaeus* were recorded in Darjeeling, Kalimpong (ZSI, 2010). Some species of *Haplosonyx* were reported from

Sikkim and Himalayas (Kimoto, 1967). Adults of the corm-borer emerge during middle of May and peak adult activity occurred between June and August. They are in bright metallic blue (90%) and pink (10%) colored on the dorsal side, yellowish on the ventral side with orange-colored head and thorax and feed on leaves making circular trenches of one-inch size. They hide inside the leaf/petiole sheath and each plant harbors 3 to 12 beetles. Adult beetles also hide in the cracks and crevices of the soil around the taro plant. The adult female lays eggs in groups of 80-100 on leaf petiole sheath above the ground. Soon after hatching, the tiny grubs bore into the shoot and consume the developing corm resulting in the death of the plant. A maximum of 75 grubs were found per plant. The damaged plant withered, wilted, become yellow and emitted foul smell (Korada, 2013). The adults consume leaves by damaging up to 20-30%. Crop losses are up to 50-60% during severe infestation. The pest has been recorded infesting wild taro species *viz*., *C. esculent*a var. *sylvestris*, *C. affinis*, and *C. fallax* distributed in high altitudes up to 3000m amsl (Korada, 2013).

Management

The adults are picked and destroyed by farmers and sometimes eaten by some of the tribes in the North-East region. The corm-borer incidence is reduced when taro is intercropped with ginger, sweet potato, yam, and maize relative to the monocrop. Two strains of entomopathogenicnematodes (*Heterohabditis indica* and *Steinernema carposae*) and fungi (*Beauveria bassiana*) cause significant increase in mortality of both adults and grubs). *H. indica* killed 95% of the grub while *S. carposae* killed 50% of the grub within 72 hours (Korada 2008, 2013).

General management practices

The following Good Agricultural Practices should be adopted for the management of various

Taropests

1. Destruction of debris, crop residues, weeds & other alternate hosts and deep summer plowing; weeding and earthing-up in rows should be done 25-30 days after sowing to prevent soil based pupation.
2. Adoption of proper crop rotation and use of resistant and tolerant varieties.
3. Use well-decomposed FYM @ 20-25 t/ha or vermicompost @ 12.5 t/ha treated with Trichoderma sp. and Pseudomonas sp. @ 5 kg/ha for seed/nursery treatment and soil application.

4. Set up yellow/blue traps/ sticky traps 15 cm. above the crop canopy for monitoring and mass trapping of Thrips, whitefly aphids @ 25-50 traps/ha.
5. Conserve the existing bio-control agents like Spiders, Coccinellids, Syrphid flies etc. in the field by avoiding, delaying and reducing the use of chemical pesticides.
6. Augment the bio-control agents like egg parasitoids- Trichogramma sp., larval parasitoid- Bracon sp., *Campoletis chlorideae,* predators like *Chrysopa sp., Coccinellasp.* (Sushil et al., n.d.).

Management of diseases

Major diseases affecting taro are taro leaf blight (TLB) disease, and the diseases caused by *Dasheen Mosaic Virus, Taro Bacilliform Virus.* Other viruses reported in taro are *Groundnut Bud Necrosis Virus* (GBNV) and *Konjac mosaic virus* (KoMV).

Taro leaf blight

Occurrence

Taro production is highly affected by many biotic and abiotic factors. Taro leaf blight (TLB) caused by *Phytophthora colocasiae* Rac., the most destructive disease of taro (Misra 1999). Butler and Kulkarni (1913) reported TLB for the first time in India. It has been observed at various places in India since 1905 causing 25-50% loss in yield. In Odisha, out of 14fieldssurveyedd, 93% of fields had TLB infection while 80% of fields had more than 80% incidence (Misra 1996a). There was a strong positive correlation between disease severity and yield loss in the farmer's field and experimental farm of the Regional Centre of ICAR-CTCRI (Misra 1996a). The disease is more prevalent in northern and eastern parts of India, where maximum cultivation of taro is being practiced. In South India, the occurrence of the disease is irregular, but in serious proportions (Misra and Chowdhury, 1997). Both *eddoe* and *dasheen* types of taro are equally susceptible to TLB disease. The disease appears with the onset of monsoon and continues till rainy season. Occasional sunlight with intermittent rain is more favorable for disease severity compared to prolonged cloudy weather with rainfall. TLB appears as small, water-soaked spots that rapidly increase in size and number leading to complete destruction of leaf lamina. In the infected circular zone in leaves, whitish, thread-like fungal mycelium surrounding diseased spots and orange droplets produced as a result of host-pathogen interaction can be visualized. The extent of plants infected, leaves infected, leaf area damage, disease severity, dead leaves in tolerant varieties varied between 16.5 and 25%, 4 and 8.6%, 0-8.6%, 2 and 13.5%, 0 and 9.6% respectively, whereas in susceptible cultivars these parameters varied between 29 and 100%, 10.5 and 51.5%, 11 and 38.7%, 14 and 56.5%, 12.5 and 62.5% respectively. However, none of these parameters had a definite positive correlation with the cormel yield (Misra, 1999) whereas disease severity had negative correlation with cormel yield (Alam et al., 1996). Cultivars with lower leaf infection, leaf area damage, disease severity and dead leaves had cormel yield ranging between 55 and 135 g/plant whereas cultivars with higher values of these parameters had cormel yield ranging between 53 and 185 g/plant (Misra, 1999). Besides leaves, the pathogen also causes serious post-harvest decay of corms (Misra et al., 2008a; Padmaja, 2013).

The pathogen

Biology

The mycelium of *P. colocasiae* is aseptate, hyaline, coenocytic with hyphal width of 1 μm and hyphal swellings were absent. The haustoria are slender, long and un-branched. The growth of the fungus is optimum at pH 6.5 and 28°C (Sahu et al. 2000; Padmaja, 2013). The sporangiophores are very slender, un-branched and extremely narrow at the tip and measure up to 50 μm in length. The sporangia are elongated; lemon- or pear-shaped and measure 38-60 × 18-26 μm. However, Misra (1996b) reported sporangial length and width as > 100 μm x 50 μm. They germinate directly or indirectly depending on the weather conditions. When indirectly germinates (20-21°C), as many as 12 reniform, biflagellate zoospores are released, which convert to cysts and germinate after 30 minutes (Misra 1996b). Indirect germination of zoosporangia occurred in water in less than 2 hr at optimum temperature (20- 21°C) and zoospores germinated in less than half an hour after release. Direct germination occurred in 5-6 h at 20- 28°C. Thick-walled, round, hyaline chlamydospores are also produced, especially in old cultures (Thankappan, 1985; Misra, 1999).

Variability

Phenotypic variability

Phenotypic techniques were employed for assessing and exploiting the genetic variability among four isolates of *P. colocasiae* obtained from a fine spatial scale (multiple leaf blight lesions on single taro leaf). The infected taro leaves were collected from experimental fields of ICAR- CTCRI, Thiruvananthapuram. Phenotypic characters such as virulence, morphology and mating type showed no variation (Nath et al., 2013a, d). Whereas, parameters such as virulence, colony morphology, mating type and metalaxyl sensitivity varied among isolates collected from different locations of Kerala, and Odisha (Nath et al., 2015a; 2016a). In general, isolates from the same field/region has similar growth patterns. Sexual reproduction is one of the most important biological events occurring during the lifecycle of *Phytophthora,* to produce sexual spore oospores. The heterothallic (self-sterile) members require pairing of two compatibility types, A1 and A2, whereas the homothallic members can produce oospores even in a single culture. The majority of the isolates (44) of *P. colocasiae* tested were of the A1 mating type. Only six isolates were found to be of the A2 mating type. Compatible mating types were not found in the same field/region. Of the 50 isolates of *P. colocasiae* studied, 26 (52%) were classified as sensitive, 19 (38%) were moderately resistant and 5 (10%) were resistant to metalaxyl (Nath et al., 2015a). Isolates of *P. colocasiae* obtained from different locations of Andhra Pradesh and Telangana states exhibited considerable differences in morphological and cultural parameters (Padmaja, 2013; Padmaja et al., 2017). The sporangium was semi-papillate and either globose/ ovoid. The color of the colony in isolates was white or dull white and the mycelium was slightly fluffy and sparse. Growth rate varied from 11.4 mm /day to 12.6 mm/day; sporangial length ranged from 21.2 μm to 24.3 μm and breadth from 14.9 μm to 17.2 μm; oospore diameter ranged from 19.2 μm to 27.8 μm.

Molecular variability

Inter and intra-specific genetic diversity existing among *P. colocasiae* isolates collected from different parts of the country was well established by adopting various molecular approaches (Misra et al., 2011; Nath et al., 2013, 2014a, b, 2015a, b, 2016a; Archana et al., 2017). Analysis of molecular variance (AMOVA) showed that the majority (85%) of the diversity was present within populations of *P. colocasiae.* Dendrogram based on AFLP molecular data using the unweighted pair group method with arithmetic mean (UPGMA) classified the *P. colocasiae* isolates into two major clusters irrespective of their geographical origin. Cluster I formed the major group in 22 isolates, while cluster II had 3 isolates. Isolates were grouped irrespective of their geographical origin and displayed a high level of genetic diversity among them (Nath et al., 2013a, d). Examination of ribosomal DNA (rDNA) ITS (internal transcribed spacer) regions revealed that all the 14 isolates fell within a single cluster in phylogenetic trees, regardless of their geographic origins (Misra et al., 2011) whereas, ITS characterization of four isolates of *P. colocasiae* obtained from a fine spatial scale (multiple leaf blight lesions on single taro leaf) revealed detectable polymorphism. Cluster analysis using UPGMA revealed that individuals from the same population failed to cluster in one distinct group (Nath et al., 2013a). UPGMA analysis and Nei's gene diversity examination revealed that the *P. colocasiae* vary highly within close isolates, which was further confirmed by AMOVA analysis (Nath et al., 2014a).

The ITS sequence analysis of 50 isolates revealed 97-99% nucleotide sequence similarity to each other and 96-99% similarity among the isolates of *P. colocasiae* available in the GenBank database. Variations ranged from single base pair changes to multiple changes representing deletions and insertions (Nath et al., 2015b). Dendrogram constructed based on RAMS data using the unweighted pair group method with arithmetic mean (UPGMA) grouped the *P. colocasiae* isolates into two major clusters. No relationship was obtained between RAMS groups of the isolates and phenotypic characters/geographical origin (Nath et al., 2016a). The intraspecific and interspecific relationships among isolates and RAPD based genetic variability analysis showed marked variations among *P. colocasiae* isolates irrespective of the geographical origin points towards the ability of pathogen to acclimatize with the fluctuations in environment (Archana et al., 2017).

Diagnostic tools for detection of *P. colocasiae*

A PCR-based assay of the diagnostic region of *P. colocasiae* allows positive detection of the pathogen with greater speed and sensitivity in both infected leaves and tubers. *P. colocasiae*-specific primers designed to identify *P. colocasiae* did not amplify DNA from the other fungi and other *Phytophthora* species. The PCR assay could be performed in 3 to 4 h, including sample processing, PCRs, gel electrophoresis, and staining were used to detect leaf blight in infected leaves and tubers. The visible lesion region yielded the highest percent detection by PCR (92–100%), while areas just adjacent to infection showed the next highest percent positive samples (92-94%). Similarly, *P. colocasiae* was detected by PCR from artificially infected tubers after 16 h of post-inoculation, before the occurrence of any visible symptom. The method was also tested to detect fungal DNA in infested soils (Mishra et al., 2010b). Four subsamples of soil from each sample taken from three farms were assayed to test the presence of *P. colocasiae*; two out of three samples tested positive for *P. colocasiae*. In each one, the fungus was detected in the four sub-samples analyzed.

For the proper and accurate detection of *P. colocasiae*, Sequence characterized amplified region (SCAR) based diagnostic methods were developed for conventional as well as real-time PCR assay. Two sets of nucleic acid-based probes were also developed and Nucleic acid spot hybridization (NASH) was performed with the same. The developed primers and probes were successfully employed in detection of *P. colocasiae* from artificially as well as naturally infected tissue and soil samples, with high specificity and sensitivity (Archana et al., 2017).

Epidemiology

Survival

The corms are stored to use as the seed material for next season's crop. The fungus survives in corms and persists in soil through oospores and chlamydospores (Butler and Kulkarni, 1913; Misra et al., 2008a). *P. colocasiae* does not seem to survive much longer freely in the soils or in the infected dead leaf tissues, whereas the corm-borne inoculum of *P.colocasiae* has much more importance in the recurrence of the disease. *P. colocasiae*, like other foliar *Phytophthora*, seems to have a poor competitive saprophytic ability in soil (Narula and Mehrotra, 1984). Secondary spread occurs through sporangia and zoospores, which are shed in water but not in wind and are carried by splash between plants and plantings (Misra et al., 2008a).

Another important source of survival is wild taro plants, which grow near ponds or compost pits (Misra and Chowdhury, 1997; Misra et al., 2008a). Besides, the pathogen can also survive on many collateral hosts, which are natural hosts of *P.colocasiae* (Thankappan, 1985). *Amorphophallus paeoniifolius* and black pepper were also reported as the host for *P. colocasiae* (Paharia and Mathur, 1961). Besides *P. colocasiae* few other species of *Phytophthora viz*., *P. araceae* (Coleman) Peth., *P. palmivora* Butler, *P. parasitica* Dast. var. *pipernia* Dast., *P. nicotiana* Bredade Ham. *var*. *parasitica* Dastur also infect taro (Narasimhan, 1927; Umabala and Rao, 1972). However, the role of these species in the severity and damage or epidemiological aspects is not known. *Phytophthora colocasiae* was isolated from wild colocasia plants and the isolate could successfully infect taro leaf. Similarly, *P. colocasiae* isolate of taro origin also could infect wild taro plants. The result of the cross inoculation study suggests major role of wild taro in the survival of TLB pathogen (ICAR-CTCRI, 2019).

Occurrence and spread

Relative Humidity was directly correlated with the severity of leaf blight of taro (Gupta and Dohroo, 2012). It has been found that *Colocasia* blight epidemic occurs when night and day temperatures range between 20-22°C and 25-28°C, respectively with a relative humidity of 65% during the day and 100% at night and accompanied by overcast, rainy weather (Misra et al., 2008a). Minimum temperature and relative humidity had significant positive correlation with disease severity. The occasional sunlight with intermittent rain is more favorable for disease severity compared to prolonged cloudy weather with rainfall (Misra and Chowdhury, 1997). Mean average temperature of 30.17°C, maximum relative humidity of 93.12%, mean minimum relative humidity of 79%, and mean rainfall of 95.43 mm favored highest TLB incidence (Sarkar et al., 2017).

Initiation of TLB incidence in fields where the previous crop was infected with *P. colocasiae* starts at the lower leaves. The leaves touching the ground were the first ones to get infected and it spreads to upper leaves (ICAR-CTCRI, 2019). During rainy season as well as when there was dew, complete destruction of leaf occurred within 7-8 days of initiation of symptom. In absence of rain and dew, the infection was restricted and never spread beyond 25% of leaf area (CTCRI, 2019). An extensive survey in five districts of Nagaland during 2009 -10 cropping season in three altitudes *viz*., low hills, mid-hills and high hills in seven locations of Nagaland. The incidence of the disease was high on those landraces collected from high hills and mid-hills whereas, the landraces collected from the lower hills had a fair degree of tolerance (Pongener and Daiho, 2016).

Management of taro leaf blight

Cultural practices

Removal and destruction of infected leaves and use of healthy corms and crop rotation were recommended as control measures of TLB (Mundkur, 1949). Mulching with paddy straw or any other ground mulch results in higher corm/ cormel yield, good weed control and delays the TLB incidence (ICAR-CTCRI, 2019). Crop mulching with eupatorium, persian liliac, eucalyptus, oat straw and wheat straw delayed the appearance of disease by 5-6 days and reduced the severity of disease. Among the different plants used as mulch, use of Eupatorium - an obnoxious weed resulted in significantly higher cormel yield and decreased disease severity (Rana et al., 2007).

Shifting of planting time

Planting time can be shifted/ altered in such a way that the crucial stage of plant growth and optimum climatic conditions for disease development does not coincide with each other. In the experimental field at Regional Centre of ICAR-CTCRI, Bhubaneshwar early planting of short duration *eddoe* taro cultivars in February-March with irrigation or May with the premonsoon showers can totally escape the disease as the crop can be harvested before disease appearance which resulted in highest cormel yield (ICAR-CTCRI, 1988, 1989, 1990; Misra and Chowdhury, 1995; Misra, 1999).

Field tolerance

Among different management strategies available for taro leaf blight management, cultivation of resistant varieties is the most practical and environment-friendly strategy for disease control (Misra et al., 2008a). Different taro accessions exhibit different degrees of response against TLB disease and the differences in disease severity among taro accessions are attributed to genetic differences. TLB disease severity increases with an increase in age and late growing periods of taro evinces higher TLB disease levels than early period (Shakywar et al. 2013a, b). Taro varieties such as Muktakeshi, Pani Saru I, Pani Saru II, Narendra Arvi-1, Narendra Arvi-2, Bidhan Chaitanya (BCC-1), Indira Arvi-1, Bhu Kripa, Bhu Sree, and land races *viz*., Jankri, Nadia, Kadma exhibit tolerance to leaf blight disease. Some landraces (White Gauria, Telibari, Telia, Hangar) with higher leaf infection (29-55%), leaf area damage (14-39%), disease severity (23-57%) and dead leaves (8.5-14.7%) produced higher cormel yield ranging between 105 and 165 g/plant (Rajesh Kumar and Dubey, 1996; Misra, 1999).

Field Screening of taro accessions in fields where there is a history of leaf blight incidence is the traditional method used to locate TLB resistance. Many varieties/land races of taro tolerant to leaf blight have been reported in India. Deshmukh and Chibber (1960) identified variety, Ahina as resistant to blight. At Shimla, Himachal Pradesh, land races Poonam Pat and Sakin V were identified as resistant (Paharia and Mathur, 1964). The appearance of blight was delayed in tolerant cultivars and its subsequent spread was also slow as compared to susceptible cultivars (Misra and Singh, 1991; Misra and Chowdhury, 1997).

Many accessions were found tolerant/resistant to the disease in recent years. The genotypes, ML 2, Naya bunglow and BCC-1 were found highly resistant and BK Col-1, Gauriya, ML 9, ML 1, Nadia Local, BCC 11, Kadina Local, C3, Sunajuli, Kandha 5 and AR Col -1 were found resistant to TLB (Yadav et al., 2006). BCC-1, Topi and BCC- 21 were identified as moderately resistant (Mandi et al., 2006); BCC-1, BCC-2, BCC-8 and BCC-9 were tolerant to leaf blight pathogen whereas, BCC-11, C-62, Ce-6, Topi and Kadma local and White Goria were moderately susceptible (Das and Chakraborty, 2007). KCS-3 showed resistant reaction to all the isolates of *P. colocasiae* and Muktakeshi showed similar reaction except an isolate, RNCA-1 and Kovvuru showed differential reaction to different isolates (Padmaja, 2013). Minimum disease was recorded in cultivar NDC-1 (42.50%) and PKS-1

(50.00%) (Shakywar et al., 2013a,b). Fifty-three *P. colocasiae* tolerant genotypes identified from field screening of 145 taro genotypes at Jagdalpur during 2010-11. The lowest infection was in SGCOL-05-14 (1%) followed by IKCOL-04-05, IKCOL-04-55, SGCOL-05-23 and SGCOL-05-04 with 2% infection (Shankar et al., 2013). The TLB disease was less in Acc 35, Acc 5 and Acc 38 (Lokesh et al., 2014b) lowest percent disease incidence (33.33) was recorded from the accession, Garobal (Pongener and Daiho, 2016) while cvs. Muktakeshi, BCC-1, BCC-22, BCC-35 and Sonajuli were field tolerant to the leaf blight disease (Sarkar et al., 2017).

A rapid and reliable method (floating leaf disc assay) for screening large numbers of taro germplasm has been developed (Nath et al., 2016b). Leaf discs of taro accessions were floated on sterile water (50 ml) in sterile petri dishes. The mycelial plugs of *P. colocasiae* were placed on the adaxial side of the leaf discs and incubated for 3-4 days by maintaining high humidity (>75%) at 25°C and darkness. The leaf discs were observed daily and clear variability in lesion size was observed with various accessions. The results were positively correlated with field data (Nath et al., 2016b).

Biochemical markers

Hastening the process of identifying disease resistance to leaf blight necessitates development of bioassays that could discern resistant and susceptible accessions (Nath et al., 2014a). Differential expression of antioxidative enzymes and their isozymes were assayed in three highly resistant (DP-25, Jhankri and Dura- dim) and one highly susceptible (N-118) genotypes of taro revealed that under induced blight condition, increase in antioxidative enzymes (superoxide dismutase (SOD) and guaiacol peroxidase (GPX) activity was more in the resistant genotypes (67-92%) than that of the susceptible genotype (21-29%). Blight infected leaves showed reduction in protein content activity of nitrate reductase, increase in total soluble sugar and reducing sugar content activities of acid phosphatase and alkaline phosphatase. Changes in biochemical parameters under induced blight stress were less in resistant genotypes than that in susceptible genotypes (Sahoo et al., 2010).

P. colocasiae produces pectolytic enzymes like polygalacturonase, pectin methyl transeliminase and polymethyl galacturonase and the enzymes may play a major role in the pathogenesis of taro (Agarwal and Mehrotra 1986). The zymograms of SOD and GPX in the resistant genotypes, with pathogenic infection, showed increased activity for an anodal isoform of SOD and increased expression and/or induction of either peroxidase isoforms (POX 1 or POX 2) of GPX. In susceptible genotype N118, expression of the above isoforms was faint for SOD and nearly absent for GPX under both blight free and induced blight conditions (Sahoo et al., 2007). Resistant cultivars had 100% and 81% increase in total phenol and protein respectively in leaves when compared to susceptible cultivars. The specific activity of peroxidase remained higher while that of polyphenoloxidase remained lower in resistant cultivars as compared to susceptible cultivars (Sen et al., 2002). Biochemical changes due to Phytophthora leaf blight infection were assessed using one resistant (DP-25), two moderately resistant (Duradim and Jhankri) and one susceptible (N-118) genotypes.

Biochemical analysis of developing lesions caused by *P. colocasiae* showed that with the ingress of the pathogen and lesion expansion there was corresponding decrease in the carbohydrate, protein and oxalate contents of leaf. The decrease in oxalate content was significant between healthy leaf and leaf with water-soaked areas, whereas it was insignificant between the expanding and necrotic lesions (Sugha and Gurung, 2006). There was an increase in peroxidase, â-1, 3- glucanase, L-phenylalanine ammonia-lyase, total phenol and total sugar in the leaves of resistant (Muktakeshi) and susceptible (Telia) cultivars infected by the leaf blight pathogen. Variations in the biochemical content were genotype-dependent and the level of the different compounds except total sugar was higher in the resistant cultivar when compared to the susceptible one indicating that tolerance was related to all of the components measured (Misra et al., 2008b).

Molecular markers

Molecular markers have many benefits over the traditional phenotypic features and they are increasingly being utilized in breeding programs. Molecular markers significantly shorten the time required in breeding programs. The molecular analysis done in 14 different genotypes for leaf blight resistance revealed that the ALFP- generated bands at approximately base pair of 75 (E_{31}/M_{41}) in the highly resistant genotypes (Sharma et al., 2008). This was not found either in moderately resistant or susceptible genotypes.

Defense-related genes in taro induced by *P. colocasiae* infection were identified by inoculating taro cultivars UL-56 (compatible) and its nearly isogenic line Muktakeshi (incompatible) with virulent *P. colocasiae* isolate. Suppressive subtractive hybridization (SSH), cDNA libraries, Northern blot analysis, high throughput DNA sequencing, and bioinformatics revealed two putative resistance genes and a transcription factor (lipid transfer protein (LTP) and transcripts of the PR-proteins) among the upregulated sequences. Several candidate genes including lipid transfer proteins (LTPs), and other pathogenesis-related genes following 8-48 h of appearance of symptom in compatible and incompatible interactions, revealed higher expression in Muktakeshi (resistant) compared to UL-56 (susceptible) (Sharma et al., 2009).

The cDNA library generated by the SSH (suppression subtractive hybridization) technique revealed genes that are differentially expressed in *P. colocasiae* during a compatible interaction with taro. The genes differentially expressed identified were in three main GO categories with the highest number of ESTs belonging to the biological process. The results of reverse transcriptase quantitative PCR (RT-qPCR) assay confirmed the up-regulation of the ESTs annotated as Glucokinase, NAD (P) - binding protein, ABC transporter, zinc finger peptide and ATP synthase in the EST library. All the genes were highly expressed during the early stages (4 to 8 h.p.i) of infection (Nath et al., 2015).

The isolation and characterization of taro resistance gene analogs (RGAs) have been done for the first time. Cloning and sequencing identified three taro NBS-type sequences, (RGAs) that depicted similarity to other cloned RGA sequences (Nath et al., 2013). Quantification of RGA (resistant gene analogs) expression in resistant (Muktakeshi) and susceptible (Sree Kiran) taro varieties revealed that the target gene was up-regulated during infection in both the resistant and susceptible varieties, but the difference was that the hike in expression upon pathogen was found earlier in resistant variety than the susceptible variety and the level of expression (fold change) was also more in the resistant variety (Nath et al., 2013; Jyothi Lakshmi et al., 2018).

Elicitors for locating resistance

Under field conditions, the occurrence of disease highly depends on the prevailing weather conditions. Field screening is time-consuming, needs much labor and expense. There is also a chance of getting erroneous results due to the uneven dissemination of inoculum. Techniques based on elicitors of *P. colocasiae* can speed up and provide reliable results for *in vitro* screening of taro accessions for leaf blight resistance.

Glucan elicitors isolated from *P. colocasiae* could induce hypersensitive reaction in detached leaves, injected plants and foliar spraying in the field tolerant cultivars *viz.,* Muktakeshi and Jankhri while the induction of hypersensitive reaction was not induced or delayed in the susceptible variety Telia (Sriram et al., 2001). The detached leaves of resistant cultivars quickly developed hypersensitive reactions. Similarly, elicitor injection on resistant plants resulted in early induction of resistance (Sriram et al., 2003; Sahoo et al., 2005).

A glycoproteinaceous elicitor of 15 kDa was isolated from *P. colocasiae*. Infiltration of elicitor into taro leaves caused the formation of lesions that resemble hypersensitive response lesions. The elicitor induced activity of lipoxygenase. Cellular damage, restricted to the infiltrated zone occurred several hours later, after the infiltration of the elicitor protein. Later, systemic acquired resistance was also induced. The elicitor generated a cascade of signals acting at local, short, and long distances causing the coordinate expression of specific defence (Mishra et al., 2009). The highest level of expression of corresponding elicitor was found in *in vitro* grown mycelium and in late stages of infection when profuse sporulation and leaf necrosis occur. The elicitation of the suspension-cultured taro cells was effective in the induction of the enzyme activity of L-phenylalanine-ammonialyase, peroxidase and lipoxygenase as well as the expression of defense-related endochitinase gene (Mishra et al., 2010a). Injection of crude elicitor from virulent isolate of *P. colocasiae* (PC-15) on leaves of Muktakeshi produced visible HR response characterized by yellow hallow around the injected area after 24h. The PAL level increased twofold after 96h in virulent isolate compared to the eliciting activity observed in non-virulent isolate (Sankar et al., 2013).

Utilization of resistant accessions in breeding program

Resistant accessions identified in India can be used in breeding resistance (Misra et al., 2008). Attempts were made at ICAR-CTCRI, Thiruvananthapuram, India to develop resistant taro varieties through breeding. The maximum proportion of resistant genotypes was obtained from variety C-320 self-pollinated (66%), followed by open-pollinated progeny of C-12 (33.33%), C-78 (30%) and Nadia local (26.31%) (Pillai et al., 1993).

Chemical management

Many fungicides/organic products have been recommended for the management of TLB disease. Using tolerant cultivars like Muktakeshi and one spraying with ridomil (0.05%) the plant infection could be significantly reduced to 8% and disease to 1.5% which resulted in higher cormel yield (13 t/ha) while two spraying of aqueous neem extracts significantly reduced plant infection and disease severity to 13 and 4% respectively which resulted in higher cormel yield (12 t/ha) compared to control plants which had plant infection and disease severity to 24 and 7% respectively and produced lower cormel yield (11 t/ha). Similarly, with a highly susceptible landrace like Telia, two spraying with ridomil reduced plant infection and disease severity to 22 and 14% respectively which resulted in higher cormel yield (15 t/ha) while one spraying with ridomil and aqueous neem extract each reduced plant infection and disease severity to 24 and 17% respectively which resulted in higher cormel yield (14 t/ha) compared to untreated control plants which had 90% plant infection and 40% disease severity and produced lower cormel yield (11 t/ha) (Misra,1999). Five spraying of Dithane-M-45 (0.2%) significantly reduced plants infected, leaf area damage, disease severity and yield loss by 7%, 1%, 4% and 0% respectively, which resulted in higher cormel yield (12 t/ha) compared to untreated control plants which had 30% plant infection, 16% leaf area damage, 17% disease severity and 26% yield loss which resulted in lower cormel yield (8.5t/ha) in tolerant cultivar. Similar treatment significantly reduced plants infected, leaf area damage, disease severity and yield loss by 10%, 3%, 7%, and 0% respectively, which in turn resulted in higher cormel yield (13t/ha) compared to untreated control plants which had 76% plant infection, 40% leaf area damage, 47% disease severity and 50% yield loss which in turn resulted in lower cormel yield (6t/ha) in susceptible cultivar (Misra 1996a). Application of various other fungicides 4-5 times at 15 days intervals is effective in reducing the severity of TLB incidence. Mancozeb (0.2%) has proved very effective in successfully controlling the disease in many places (CTCRI 1988, 1989; Misra 1996a; Maheswari et al. 1999; Bhattacharyya and Saikia, 1996; Das 1997). Copper fungicides (0.1-0.2%) have proved very effective in successfully controlling the disease (Mundkur, 1949; Bhattacharyya and Saikia, 1996; Das 1997; Misra et al., 2008a; Lokesh et al., 2014a). Spraying with metalaxyl (Ridomil M272WP) at 3 kg/ha at 15-day intervals was highly effective (Ghosh and Pan, (1991). Many workers reported minimum leaf blight disease severity and maximum yield with the application of metalaxyl + mancozeb (Aggarwal and Mehrotra 1987a,b, 1988a,b; Bhattacharyya and Saikia, 1996; Das 1997; Misra et al., 2008; Sugha, 2010; Gupta and Dohroo, 2012; Lokesh et al., 2014a). Four sprays of zineb at 15-day intervals starting from the end of July to early August (Sahu et al., 1989), Captafol (Aggarwal and Mehrotra, 1987a, b, 1988; Das 1997), Chlorneb (Aggarwal and Mehrotra, 1987a,b, 1988a,b; Bhattacharyya and Saikia, 1996), Potassium phosphonate and Fenamidone 10% + mancozeb 50% (Sectin) (Lokesh et al., 2014a), Ziram (Das 1997) reduced TLB incidence in fields. The occurrence of TLB disease during heavy rain, waxy coating of leaves, cost involved for application, requirement of repeated applications and development of fungicidal resistance restricts the option.

In vitro evaluation

Complete inhibition of growth of *P. colocasiae* mycelium was observed with mancozeb, Pyrachlostrobin + Metiram and Tebuconazole at recommended concentration (0.1%). Fungicides cymoxanil, metalaxyl and copper oxy chloride reduced > 90% growth of mycelium whereas dimethomorph, thiophanate methyl, azoxystrobin reduced > 70% growth of mycelium. Pyrachlostrobin + Metiram and Tebuconazole showed 100% inhibition of the pathogen even at half the recommended concentration (0.05%) (Padmaja, 2013). Four fungicides, metalaxyl, Samarth (hexaconazole 2% EC), Biofight (0.1%) and Akoton (Sodium bicarbonate) tested against *P. colocasiae* by poisoned media technique revealed that mycelial growth of all the isolates was inhibited by metalaxyl (0.2%). Samarth (0.05%) completely inhibited mycelial growth followed by Biofight at 1% (Nath et al., 2011, 2013c). Potassium iodide and arsenic oxide inhibited mycelial growth, sporangial production, pectolytic and cellulolytic enzyme production of *P. colocasiae* (Aggrawal et al., 1993).

Compatibility of bio-agents and chemicals

For a successful integrated disease management strategy, the compatibility of potential bioagents with fungicides is essential. Integration of these two methods may enhance the effectiveness of disease control and provide better management of soil-borne diseases.

The compatibility of fungicides, mancozeb, metalaxyl, tebuconazole, cymoxanil, pyrachlostrobin + metiram with bio-agent, *Trichoderma* spp. was tested. The bioagents were least affected by the fungicides, metalaxyl followed by mancozeb and tebuconazole, whereas, Pyrachlostrobin + metiram completely inhibited *Trichoderma* spp (Padmaja, 2013). Metalaxyl M + Mancozeb (Ridomil Gold) followed by Mancozeb (Indofil M-45) were least inhibitory to *Trichoderma asperellum* (Theertha et al., 2017).

Nutrient application

Spraying of borax (500 ppm) twice at 15 days intervals showed a significant reduction in the leaf area damaged per plant by leaf blight and increased the corm/ cormel yield (Misra et al., 007). Application of Boron and Silicon to taro plants in the form of Borax and Potassium silicate at recommended dose (@ 0.75g/plant and 7g/plant) and at 150% of recommended dose (1.125 g/plant and 10.5 g/plant) resulted in reducing taro leaf blight incidence from 24.64 in control (PDI) to 3.3 -16.0 (ICAR-CTCRI-2015, 2016).

γ- Irradiation

Healthy and matured cormels of ten genotypes of taro were subjected to 10Gy γ- irradiation. The plants obtained from irradiated cormels were evaluated for leaf blight disease under *in vitro* and *in vivo* disease conditions along with the plants obtained from non-irradiated cormels. Under *in vitro* conditions, the TLB incidence such as spot diameter and number of sporangia produced was minimized with γ-irradiation as compared to the leaf discs from non-irradiated plants. The disease incidence was also minimized in the tested susceptible taro lines under γ-irradiation under artificial epiphytotic conditions. The yield reduction due to TLB infestation in irradiated plants was lower, compared with the non-irradiated plants (Sahoo et al., 2015).

Botanicals

Two foliar sprays of *Azadirachta indica* leaf extracts resulted in minimum intensity of TLB disease (26.81%) and was significantly superior over soil application of cakes of *Azadirachta indica* seeds (42.3%), *Madhuca longifolia* seeds (50.5%), *Brassica juncea* seeds (46.5%) and foliar application of black tulsi leaf extract (30%), green tulsi leaf extract (33%) and garlic bulb extracts (34.8%). All the tested seed cakes as well as leaf extract could significantly reduce TLB incidence compared to the untreated plants (72.18%). The highest yield (12.8 t/ha) was also obtained in the plants treated with two foliar sprays of neem leaf extracts @ 10% followed by two foliar sprays with black tulsi leaf extract @ 10% (11.3 t/ha) (Shakywar, 2014).

The efficacy of eight botanicals (Phyto extracts) namely, *Nanma* (neem oil-cassava leaf extract based bioformulation) and *Menma* (cassava leaf extract based bioformulation), *Sapindus mukorossi* (seed rind extract), Neemraj (neem leaf extract), leaf extracts of *Lantana camera, Eucalyptus tereticornis,* and *Vitex negundo* and seed extract of Yam bean against the TLB disease in both *in vitro* (inhibition of fungus growth based on colony diameter compared to control) as well as *in vivo* conditions (three sprays of plant extracts applied at an interval of 1 month starting from initiation of disease symptoms) was reported by Saykar et al., (2018). Under *in vitro* conditions, among these botanicals, the maximum percent inhibition of pathogen (94.07%) was observed with *Sapindus mukorossi* seed rind extract which was significantly superior to all other treatments. It was followed by *Nanma* (90.36%) and Neemraj (72.58%). Under *in vivo* conditions, among above-mentioned plant extracts, the minimum disease incidence was recorded in taro plants sprayed with *Sapindus mukorossi* (33.67%). It was followed by Nanma (37.00%) and Neemraj (39.67%). This resulted in maximum disease control of 48.09, 42.95 and 38.83% respectively.

Biological Control

Several fungi and bacteria isolated from phylloplane and rhizosphere regions of taro plants completely inhibited the growth of *P. colocasiae* under *in vitro* conditions (Misra et al. 2001). Apart from this, many microbes including endophytes obtained from various sources viz., phyllosphere, rhizosphere and organic amendments were also effectively checked the growth of *P. colocasiae* under *in vitro* and *in vivo* conditions (Veena et al., 2011, 2013; Lakshmipriya et al., 2016a, b; Sujina et al., 2017)

Phylloplane microflora

Myrothecium roridum, 3 *Streptomyces* sp. and two bacterial isolates from phylloplane microflora of *C. esculenta* were antagonistic to *P. colocasiae* on dual culturing (Narula and Mehrotra, 1981, 1987). *In vivo*, the bacteria reduced the disease incidence up to 43%; *Streptomyces albidoflavus* reduced infection by 90-93% and *S. diastaticus* by 76%. Among fungi, *Botrytis cinerea* resulted in the best reduction of (33%) of *Phytophthora* infection. *Trichoderma* spp and few bacterial isolates obtained from phylloplane of taro plants inhibited the radial growth of *P. colocasiae* under *in vitro* conditions (Padmaja, 2013).

Rhizosphere microflora

Trichoderma viride, *T. harzianum* and *Gliocladium virens* have potential mycoparasitic or hyperparasitic activities against *P. colocasiae in vitro* through several morphological changes like coiling of hyphae, formation of haustoria like structures, disorganization of host cell contents and penetration into host hyphae (Sawant, 1995; Pan and Ghosh, 1997).

Based on pathogen suppression through confrontation, production of diffusible metabolites and volatiles; IAA production and growth promotion potential, sixteen bacterial isolates were selected and identified based on 16s r RNA gene sequencing viz., *Bacillus amyloliquefaciens* (four isolates), *B. cereus* (2), *B. licheniformis*, *B. subtilis*, *Pseudomonas aeruginosa* (6), *P. alkylphenolica* and *Myroides odoratimimus* (ICAR-CTCRI-2015, 2018). Bio-priming is a technique of seed treatment that integrates biological (inoculation of cormels with beneficial organisms) and physiological aspects of disease control.

Cormels of taro were bio-primed with six *Trichoderma* isolates and four bacterial isolates, viz., *B. subtilis, B. licheniformis* and *B. amyloliquefaciens* (2 isolates). All the 10 isolates could significantly increase the height of the plant, leaf length, leaf breadth, number of leaves production and yield. The final PDI was very low in all corms primed plants compared to control plants (ICAR-CTCRI-2015, 2016). In poly house, no disease incidence was noticed in taro plants due to soil application with rhizobacterial cultures S4B5, SI3B5 and S23B5. Foliar application with SI B4 and SIB3 reduced the disease severity to 0-0.33 rating compared to 2.66 in control. Under field conditions, tuber treatment with SI B3, soil application of S13B5 or foliar application with SI B4 and SII B3 reduced the disease severity and increased the yield compared to untreated pathogen-inoculated control plants. Integrated application of these bacteria through seed treatment, soil treatment and foliar spray reduced the leaf area damage due to TLB significantly (by 28 to 41%) during different stage of disease incidence (Sriram and Misra, 2007).

Endophytes

Colonization of taro roots by *Piriformospora indica,* an endophytic mycorrhiza-like fungus induced leaf blight resistance in taro plants. There was a substantial decrease in the TLB incidence in *P. indica* colonized plants of susceptible (Sree Kiran) and resistant (Muktakeshi) varieties.

The activity of defense enzymes like chitinase, β-1, 3 glucanase and total phenol increased in *P. indica* colonized plants as compared to un-inoculated plants during initial hours of infection. Suppression Subtractive Hybridization revealed differentially expressed genes in *P. indica* colonized plants upon *P. colocasiae* infection. Various genes like senescence-associated genes, cytochrome P450, Delta (12) Oleic acid desaturase and calcium-dependent protein kinase that take part in different defense-related pathways were identified upon Blast2Go program (Lakshmipriya et al., 2016b).

Increased rate of sprouting in taro tubers was observed due to treatment with nanoparticles (NPs) and a management strategy was developed for taro leaf blight using nano-biocomposite (ZnO nanoparticles and antagonistic microbes) as a biocontrol. The sprouting rate, growth promotion and yield of taro tubers were significantly good in nano-bio-composite treatment on comparison with absolute control (Sreelatha et al., (Unpublished) 2019).

Organic amendments

Microbes isolated from vermicompost showed differential response to *P. colocasiae* and inhibition was mainly due to the production of diffusible metabolites by the organisms. The most potent fungal, bacterial and actinomycete isolates identified are *Trichoderma harzianum, Bacillus subtilis* and *Streptomyces* spp. respectively (Veena et al., 2011). The disease suppression potential of these microorganisms varied with the source of vermicompost. Vermicompost/ vermiwash treated taro plants showed <10% TLB incidence. Yield increase of 14–70 % was also observed in treated taro plants relative to untreated plants (Veena et al., 2013).

Integrated Management of TLB

Phytophthora leaf blight of taro can be effectively managed by the use of resistant cv. Muktakeshi with mancozeb (0.25%) sprays after the first appearance of the disease symptoms and another spray with ridomil MZ (0.2%) at 15 days after the spraying of mancozeb (Misra et al., 2007). Short-duration crop varieties with early planting i.e., in March combined with one protective spray with mancozeb (0.2%) at 45 days after planting followed by one spray with metalaxyl (0.05%) at 60 days after planting, intercropping with non-host crops like okra, use of disease-free planting material and tuber treatment of planting material with *Trichoderma viride* has been formulated as an IDM package for the management of the taro blight (Misra et al., 2001).

Seed treatment (10 g/kg seed) and soil application of *Trichoderma viride* @ 2 kg/ha at the time of planting + foliar application of mancozeb (0.2%) resulted in significant reduction of TLB and higher cormel yield (Padmaja, 2013; Padmaja et al., 2017). Integration of one-hour planting material dip in Indofil M-45, mulching with *Eupatorium* plant leaves and fortnightly foliar sprays of 0.2% ridomil MZ (thrice) resulted in 76.9% reduction of disease with 131.3% increase in cormel yield over unprotected crop (Rana et al., 2007).

In field trial on management of TLB at regional center of ICAR-CTCRI, Bhubaneswar, treatment of planting material with *Trichoderma* + 2 foliar sprays with CTCRI bio-formulation at 45 and 75 DAP resulted in highest yield (26.6 t/ha) and least blight (4.0%) incidence (ICAR-CTCRI, 2015). Similarly, in another field trial, least PDI (25%) was observed due to cormel treatment with *Bacillus amyloliquefaciens* + *B. amyloliquefaciens* incorporated vermicompost followed by cormel treatment with *Trichoderma asperellum* + *T. asperellum* incorporated vermicompost (31.67 against 52.08 in control. The highest yield (6.09 t/ha) was also recorded in plants raised from cormels treated with *Bacillus amyloliquefaciens* + *B. amyloliquefaciens* incorporated vermicompost against 2.6 t/ha in control (ICAR-CTCRI 2018).

Viral diseases

Taro plants having viral infection exhibits prominent symptoms like mosaic; prominent whitish or faint feathery mosaics; mild vein clearing and chlorosis on the midrib and leaf margins; deformed, crinkled or curling, leaf puckering, mottling. Asymptomatic samples showed no prominent symptoms other than mild indistinct chlorosis or variegation. Across globe, five main viruses reported infecting taro is *Dasheen mosaic virus* (DsMV), *Colocasia bobone disease virus* (CBDV), *Taro bacilliform virus* (TaBV), *Taro vein chlorosis virus* (TaVCV) and *Taro reovirus* (TaRV). Out of the major five taro-affecting viruses worldwide, *Dasheen Mosaic Virus* belonging to *Potyvirus* and *Taro Bacilliform Virus* belonging to *Badnavirus* are widely found regionally. Sample studies showed mixed infections caused by DsMV and TaBV on both Taro and Tannia. *Taro vein chlorosis virus* and *Colocasia Bobone Disease Virus* affecting taro in the Pacific islands is absent in India (Adil, 2014a, b; Aarthy, 2017). Dasheen mosaic virus infection in taro was diagnosed using specific primers (Babu et al., 2010, 2011). Adil (2014a,b) screened taro leaf samples for *Dasheen Mosaic Virus, Taro Bacilliform Virus, Taro vein chlorosis virus* and *Colocasia Bobone disease virus* using both genus and species-specific primers. Fifteen samples out of 22 showed DsMV infection in PCR while ten samples showed TaBV infection. While mixed infection by DsMV and TaBV was found in 6 samples there was a lone case of positive for TaBV-like sequence in one sample (N28). Both TaVCV and CBDV screening through PCR gave negative results for all samples. Molecular analysis with specific primers (TaBV like sequences) identified a new member among the badnavirus, Taro bacilliform CH virus, which was not previously detected in India (Aarathy, 2017).

In India, a mosaic disease on taro has been reported from Thiruvananthapuram in the early 80's, with a typical symptom resembling that of DsMV (Malathi and Shanta, 1981). Occurrence of mosaic disease on taro in northeastern states of India has also been recorded (Swamy et al., 2002).

Sivaprasad et al., (2011) reported Groundnut Bud Necrosis Virus (GBNV) infecting taro for the first time. GBNV is a member of the genus Tospovirus. For the first time in India, Konjac mosaic virus (KoMV) belonging to the genus *Potyvirus* has also been reported to be infecting three aroid plant species *C. esculenta*, *Caladium* sp., and *Dieffenbachia* sp. (Manikonda et al., 2010). The associated symptoms were mosaic, chlorotic feathery mottling, chlorotic spots, leaf deformation and chlorotic ring spots.

Storage rots

A survey of fungi associated with post-harvest deterioration of taro tubers was conducted in Bhubaneswar, Odisha, India, during 2014-15. Rotten samples were collected from markets and fungi viz., *Aspergillus niger*, *A.*

flavus, Geotrichum candidum, Rhizopus oryzae were observed to cause the damage. *R. oryzae* and *G. candidum* had highest percentage frequency of occurrence while *A. flavus* had the least frequency. *R. oryzae* and *A. flavus* were most pathogenic leading to rapid disintegration of the infected tubers within 20 days of inoculation (Khatoon et al., 2016). *Lasiodiplodia (syn. Botryodiplodia) theobrome*, *Phytophthora colocasiae*, *Sclerotium rolfsii*, *Fusarium* sp., *Rhizopus* sp., *Aspergillus* sp. *Penicillium* sp. were identified as the causal organisms causing 8-10% post-harvest loss in taro (ICAR-CTCRI, 2015).

Rhizobacteria treatment helped significantly in reducing the storage losses. The storage loss of tubers harvested from rhizobacteria treated plots ranged from 4.14 to 21.24% as compared to 26.02 and 21.78% in fungicide treated and control plots, respectively, resulting in 18 to 36% higher yield in the field trials (Sriram and Misra, 2007).

Challenges and Prospects of taro in India

Challenges

Taro requires adequate soil moisture throughout its crop growth period of 4 to 5 months except towards the end of corm/cormel maturity (3-4 weeks before harvest). It is highly sensitive to WDS conditions and therefore requires irrigation once every 5 -7 days depending on the soil water holding capacity and prevailing weather conditions. As good quality water will be a scarce commodity in future, precision farming technologies should be introduced for taro cultivation for enhancing water productivity. High yield coupled with high acridity, TLB susceptibility of taro varieties is a challenge and warrants improvement of such varieties for these traits. Adaptability of taro to salinity of soil/irrigation water is not known and therefore warrants investigation. Presence of oxalic acid in the form of oxalate crystals in some promising varieties and consumption of such varieties without adequate processing may lead to kidney-related illness. Shorter shelf life of fresh taro corms/cormels for 1 or 2 months may lead to loss of planting materials.

Prospects

Taro is adapted to shade and waterlogged conditions. It can be successfully intercropped with other crops as well as under plantation crops like coconut, areca nut, coco etc. Some varieties can produce economically profitable yield in 5 months and therefore can be taken up in sequential cropping along with other short-duration vegetable crops. In a front line demonstration of variety Muktakeshi (*eddoe* type) in Odisha under National Agricultural Innovation Project (NAIP) during the year 2011-12 resulted in net return of US$ 2,036/ha (Rs. 148,600/ha) with the benefit-cost ratio of 3.28

(Lenka et al., 2012). Sixty-two demonstrations conducted in Koraput (Odisha), Narayanpur (Chhattisgarh) and Deogarh (Jharkhand) on taro (Muktakeshi) resulted in an average cormel yield of 13 t/ha, gross US$ 2,678/ha (Rs. 196,500/ha) and net US$ 1,589/ha (Rs. 116,000/ha) return with B:C ratio of 2.44 (Misra et al., 2013). A commercial crop of swamp taro can give an income of US$ 7,12/ha (Rs.52,000/ha) (Saud and Barua, 2000). In Assam, a gross return of US$ 3,781/ha (Rs. 276,050/ha) and a net return of US$ 3,028/ha (Rs. 221,050/ha) was obtained with the corm yield of 17 t/ha (Saud et al., 2013a). These reports indicate that taro has a vast scope as a highly remunerative crop in India.

Taro fetches relatively a good consumer market price compared to other root and tuber crops in Indian markets (Table 6). However, elimination of traders/commission agents, wholesalers, retailers (middlemen) and direct selling can fetch good profit to farmers.

Table. 6. Farm gate / Consumer price in India

Root and tuber	Farmers price (US $)/kg	Consumer price (US $)/kg
Cassava	0.14-0.28	0.21-0.56
Sweet potato	0.14-0.21	0.28-0.70
Yam	0.28-0.35	0.56-0.84
Elephant foot yam	0.21-0.35	0.42-0.84
Taro	0.21-0.28	0.42-0.70
Tannia	0.42-0.56	0.70-1.12
Arrow root	0.14-0.28	0.28-0.56
Yam bean	0.21-0.28	0.42-0.56

The costs and returns in production of taro are given in Table 7. The total cost of production of taro worked out to be US$ 1,711/ha (Rs. 124,925/ha). Human labor was the major component of total cost and its share in total costs was about 47% followed by seed materials (20%) and manures (10%). The estimated average yield of taro was 15.5 t/ha. The gross and net returns of US$ 4,459 (Rs. 325,500) and US$ 2,748 (Rs. 200,575) per ha were realized from production of taro. The benefit-cost ratio of taro is estimated to be 2.6.

Table 7. Costs and returns in production of taro

Particulars	Cost /ha		(Rs./ha)	Percent
	US$	Rs.		
Land Preparation	103	7,500		6.00
Human labor	801	58,500		46.83
Machine labor	103	7,500		6.00
Seed materials	351	25,600		20.49
Manures	171	12,500		10.01
Fertilizers	100	7,325		5.86
Plant protection chemicals	82	6,000		4.80
Total cost	1,711	124,925		100
Taro cormels and corms (tonnes)			15.5	
Price (tonnes)	288		21,000	
Gross return	4,459		325,500	
Net return	2,748		200,575	
Benefit-cost ratio			2.60	

(Source: Dr. Prakash, Scientist Agricultural Economics, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, India, personal communication)

Marketing pattern

In India, taro is available in different states throughout the year either by local production or procured from other states and this is because of differences in planting time. As the taro farm holdings are small, quantity available with the farmers for sale is also small. Farmers, village traders/commission agents, wholesalers, retailers and consumers are the different market functionaries involved in the process of marketing the produce from farmers in Uttar Pradesh to a consumer at Azadpur market. However, marketing is done mostly by commission agents. The producer share in consumer price was 57% and the price spread was Rs.1148 per 100 kg of taro. The marketing cost and margin constituted 33 and 67% respectively. As the number of market functionaries increases, marketing cost and margin also rise up resulting in lower producers' share in consumers´ rupee. The major market centers in India are Azadpur market in Uttar Pradesh (UP), Pandhana and Khandwa APMC in Madhya Pradesh (M.P), Azadpur market in West Bengal (WB) and local sales in UP, MP, Andhra Pradesh (AP), Odisha and Chennai (Tamil Nadu) (Srinivas et al., 2012).

Livelihood assessment of taro and paddy

Taro is one of the major tuber crops grown in Odisha for livelihood and food security of the poor and marginal farmers. Farmers have their livelihood strategies to cope with the environment and to sustain their living. Livelihood assessment of the taro growers and comparing them with other important crop growers i.e. paddy was done in Nayagarh districts of Odisha by identifying different assets possessed by the growers and their contribution to their livelihood during 2019 (Table 11). The rural sustainable livelihood index was marginally more for paddy (60) than taro growers (59). The human capital index was more for paddy growers (66) when compared to taro growers (50). Physical capital was high for taro growers (73.6). Physical capital was more when compared to all other capitals which are an indicator for the development of the agricultural villages in Odisha. Social capital is the same for both the growers (62). Financial capital was more for taro growers (40.8). Natural capital was also higher for taro growers (69) than paddy growers (63.3). Similarities between capitals of taro and paddy growers are in decreasing order concerning physical, natural, social, human and financial capitals.

Table 7. Comparison of the different capitals between taro and paddy growers.

Capitals	**Taro growers (n=50)**	**Paddy growers (n=50)**	**Ranking**
Human Capital	50.0	66.0	IV
Physical Capital	73.6	69.5	I
Social Capital	62.0	62.0	III
Financial Capital	40.8	37.1	V
Natural Capital	69.0	63.3	II
Rural Sustainable Livelihood Index	59.0	60.0	
Physical > Natural > Social > Human > Financial			

(Dr. Sheela Immanuel et al., Principal Scientist Agricultural Economics, ICAR-Central Tuber Crops Research Institute, Thiruvananthapuram, India, personal communication).

Export potential

Azadpur market is the largest distribution center of taro after Baruvasagar and Pandhana markets. Large arrivals of taro are from May to October to this market. Taro from Azadpur market is supplied to local consumers and to Punjab, Himachal Pradesh, Haryana, Hyderabad, Mumbai, Ahmedabad and Pune. The produce is packed in different size gunny bags depending on the place of marketing and transportation requirements. Medium-sized taro tubers are graded and packed in 20 kg baskets/trays and exported to the UK, UAE, USA and Gulf countries. Although no authentic record is available, it appears that taro is exported by air from New Delhi and Mumbai to UK and Gulf countries. On average 15 to 20 tonnes of taro are exported annually.

SWOT analysis

Strength

- Ability to thrive under waterlogged conditions/submergence under flood.
- Tolerance to soil salinity.
- Excellent response to organic mode of nutrient management.
- Tolerant to shaded conditions can be an insurance crop as intercrop in coconut, banana, rubber and other plantations.
- Suitable for mixed cropping with main pulses and short-duration vegetables.
- Adapted to high CO_2 environment up to 1000 ppm CO_2.
- Susceptible to less number of major pests.
- High productivity with marginal plant nutrient management. Presence of sufficient buds on corm surface enables the propagation easier with mini setts / small-sized planting materials with enhanced planting material availability.
- Long duration of the crop (5-7 months)-can accommodate well other short-duration crops as a intercropping system.

Weakness

- Environmental conditions associated with flowering have not been studied.
- Non-flowering of varieties under some locations.
- High water requirement.
- Highly susceptible to heat (40^{o}C) and drought stresses.
- High susceptibility to the incidence of leaf blight especially during humid, rainy season.
- Acridity of corms and cormels.

Opportunities

- Increasing demand for planting materials and potential for area expansion under taro.

- Popularization of minisett technology as a source of quick and easy method of planting material production in taro.
- In areas with fertile productive soils, taro can be recommended as a nutritious tuberous vegetable for organic farming.
- Average potential yield of improved taro varies is 25 t/ha whereas, average yield is 17.8 t/ha. So, there is a yield gap of 7 t/ha. By adopting recommended, best water and nutrient management practices and plant protection measures, the prevailing yield gap can be reduced and potential yield can be achieved.
- Can fit well into crop rotation, intercropping and a component crop in mixed cropping/sequential cropping.

Threats

- Under the global environmental change, especially under severe drought and heat, the cultivation of the crop without irrigation will be difficult.
- Due to climate change and change in seasonal variation, as the climatic factors are unpredictable, the cultivation of taro deserves special care in terms of photoperiod, temperature and precipitation.
- Taro leaf blight especially during humid climatic situations with frequent rainfall is a serious threat to taro cultivation even though the crop has adequate moisture in the soil for its good growth and yield.

Technologies

- Flower induction technique with chemicals such as GA_3 and ascorbic acid.
- Regeneration protocol and rapid multiplication technique for eddoe and dasheen taro.
- Precision farming technology.
- PoPs for INM for taro involving conjoint use of FYM @ 10 t ha^{-1} along with NPK @80:50:80 kg ha^{-1}
- PoPs for INM for taro for different agro-climatic zones of the country.
- PoPs for INM for taro intercropping with coconut.
- Foliar nutrition for enhancing yield as well as better utilization of nutrients.
- PoPs for Organic production of taro.
- PoPs for taro-based intercropping systems with maize, pigeon pea, black gram, green gram for augmenting farmers' income and land utilization efficiency.

High impact technologies

- Taro varieties such as Muktakeshi, Pani Saru I, Pani saru II, Narendra Arvi-1, Narendra Arvi-2, Bidhan Chaitanya (BCC-1), Indira Arvi-1, Bhu Kripa, Bhu Sree exhibit resistance to leaf blight disease.
- PoPs for taro-based intercropping systems with maize, pigeon pea, black gram, green gram for augmenting farmers' income and land utilization efficiency.
- Foliar nutrition for enhancing yield as well as better utilization of nutrients.
- PoPs for Organic production of taro.
- Regeneration protocol and rapid multiplication technique for eddoe and dasheen taro.
- TLB tolerant and high yielding varieties such as Muktakeshi, Pani Saru I & II, Sree Kiran, Sree Pallavi, Bhu Kripa.
- PoPs for management of TLB.

Recommendations

- Establishment of seed chain, seed villages for high yielding varieties involving Agriculture Departments, Farmers Producing Organizations (FPOs) and entrepreneurs.
- Training, capacity building of stakeholders for enhancing productivity and ecological sustainability.
- Factors influencing flowering need to be developed.
- Varieties tolerant to high-temperature stress (> 40^{o}C) need to be identified/developed.
- Shorter duration (4 months) *eddoe* and *dasheen* varieties need to be developed.
- Developing innovative, ICT-based technologies for reducing the cost of production need to be worked out.

Conclusion

It is evident from the literature that extensive research has been done/in progress on taro production and protection for sustainable taro production in India. Average potential yield of improved taro varies is 25 t/ha whereas, average yield is 17.8 t/ha. So, there is a yield gap of 7 t/ha. By adopting recommended, best water and nutrient management practices and plant protection measures, the prevailing yield gap can be reduced and potential yield can be achieved. Huge demand for planting materials of improved varieties remains a challenge and needs to be addressed. Many PoPs for production and protection of taro and value addition technologies available in India can be exchanged with SAARC countries for mutual benefits.

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Chapter 11

Collection and conservation of Aroids in Bangladesh Agriculture University Germplasm Centre (GPC)

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Abstract

Aroids or taro are found to be grown almost everywhere in Bangladesh both in cultivated and wild forms. It is a popular vegetable both in rural and urban areas of Bangladesh. Leaves are recommended to eat for preventing night blindness in children. Generally, taro has been cultivated by small farmers as a vegetable. Several available local varieties such as mukhi kachu (*Colocasia esculanta*), pani kachu/ Water taro (*Colocasia stoloniferous)*, ol kachu/ Elephant foot yam (*Amorphophallus campanulatus*), Man Kachu/ Giant taro (*Alocasia macrorrhiza*), etc. are grown for household consumption and earning cash by selling in local markets. The whole taro plant is used as a vegetable in Bangladesh, but some varieties are specific in their use, like Dud Kachu and Mowlavi Kachu (*Xannthosoma sp.*) are mainly cultivated in some areas for their stem and foliage and mukhi kachu (*Colocasia esculanta*) is mainly cultivated for corms. Due to nutritional value, popularity, and potential to combat hidden hunger, Germplasm Centre (GPC) of Bangladesh Agricultural University (BAU), Mymensingh under the Fruit Tree Improvement project (FTIP) has undertaken an initiative to collect locally available germplasm of taro/aroids for characterization and conservation aiming to use in future research on variety development programs. At present there are forty-five germplasm in four genera of Araceae family (*Alocasia*, *Amorphophallus, Colocasia,* and *Xanthosoma)* are collected, characterized, and conserved in BAU-GPC. Out of forty-five collected germplasm, four varieties have already been released as variety. Considering its economic importance and nutritional value it is of utmost need to collect and conservation of taro germplasm for promoting taro in Bangladesh.

Introduction

Aroids, monocotyledonous herbaceous plants of the family Araceae is one of the oldest domesticated groups of plants that grow in moist and shady places. In Araceae family only four genera such as *Alocasia*, *Amorphophallus*, *Colocasia*, *Xanthosoma* that have been cultivated in Bangladesh (Ahmed, 1974). *Alocasia* may be native in Sri Lanka or India, afterwards, it spreads Eastwards to Oceania, Micronesia, Polynesia, and Melanesia (Paul and Bari, 2008). Archaeological studies indicate that *Alocasia* and *Colocasia* have been found in the Solomon Islands as early as 28000 years ago (Loy et al., 1992). *Colocasia* (Taro) has been described in an ancient Chinese book of about 100 BC (Tanimono, 1998). *Colocasia* was carried in the Caribbean and tropical America on slave ships as a source of food (Paul and Bari, 2008). Salad Kachu (*Colocasia gigantea*) was found in Vietnam and Java Island (Hooker, 1894), and has been cultivated in Southeast Asia and East Asia (Mathews, 1991; Boyce, 2010). *Xanthosoma sp.* or Cocoyam is native to the American continent and reached West Africa between 16th and 17th centuries and was spread further by Voyagers, Traders, Explores, and Missionaries. It has been domesticated and cultivated during pre-Columbian times (Wilson, 1984; Montaldo, 1991). In the 19th century, Cocoyam was introduced into Asia and the Pacific, and North America (Brown, 2000). In recent years the tendency has been to give the name of *X. sagittifolium* to all cultivated *Xanthosoma* (Giacometti and Leon, 1994).

However, worldwide taro ranks 14th among staple vegetable crops with about 12 million tonnes, from about 2 million hectares with an average production is about 6.5 t/ha (Singh et al., 2012). Most of the production comes from *Colocasia* and *Xanthosoma.* In addition, taro is an export commodity in many countries like Fiji and Cook Islands. The food processed products have been made from taro flour and successfully marketed in Hawaii and India (Paul and Bari, 2008).

Taro/aroids consist of a group of aroids monocotyledonous herbaceous plants of the family Araceae, occupying a significant place in the agriculture of the South Asian Region. The aroids rarely enter into the world of commerce as they are mostly grown in subsistence agricultural systems and for local markets and play a substantial role in the food security of millions of people in the tropics. In Oceania particularly, taro plays a critical role in the household, community, and national food security. Since both corms and leaves are usually consumed, taro supplies much-needed protein, vitamins and minerals, in addition to carbohydrate energy. Taro is now the fifth most consumed root and tuber vegetable (Macharia et al., 2014). Even though it has been neglected by crop breeders and conservationists. The socio-cultural importance of taro in the region is very high. The crop has evolved to be an integral part of the culture and features prominently in festivals, social gift-giving, and the discharge of social obligations. More recently, taro has become a source of income for individuals, and an earner of foreign exchange. Its role in rural development has therefore been increasing, especially with respect to the provision of employment and the alleviation of rural poverty.

In Bangladesh, different types of aroid genera and species have been cultivated in different areas or districts which can be categorized into edible, nonedible and medicinal. Aroids are used as vegetable for human nutrition and animals' feed. But lack of proper agronomical practices and research, many species of this family have already been extinct, some are vulnerable and some are available at present. The edible aroid species are *Colocasia esculenta* (L.) Schott. that local name taro (Mukhi Kachu, Panchamukhi Kachu, Pani Kachu, and Poidnyl Kachu); *Alocasia macrorrhiza* (Man Kachu) and *Alocasia indica* (Mugur Kachu); *Amorphophallus paeniifolius* (Ol Madrasi), *Amorphophallus campanulatus* (Ol deshi) and *Amorphophallus prainii* (Talas/Perak); *Xanthosoma sagittifolium* (L.) Schott. (Dud Kachu/Mowlavi Kachu/ Surma Kachu); *Xanthosoma caracu* (Bombay Kachu/Mowlavi Kachu); *Xanthosoma atrovirens* (Shaheby/ Mowlavi Kachu) and *Xanthosoma robustum* (Maffafa/ Mowlavi Kachu) as reported by Paul and Bari (2008). Taro can grow well in saline soil due to its tolerance to salinity (Onwueme et al., 1994). All the edible aroids are extensively cultivated both at homesteads and commercially in Bangladesh and contribute a considerable part to the total supply of bulky vegetables during the late summer when other vegetables are scarce in the market (Siddique et al., 1988).

Edible aroids have significant importance for nutrient status, industrial and medicinal values. Aroids are considered a rich source of carbohydrates, calcium, iron, protein, vitamins and minerals (Verma et al., 1996). For industrial purpose, taro alcohol can be used as a fuel for remote islands, taro starch as a raw material in cosmetic and plastic manufacture as mentioned by Griffin (1982). Some species of *Alocasia*, *Amorphophalus,* and *Colocasia* possess medicinal values. The corms, leaves, and petioles of the plant have been used traditionally for the antibacterial treatment of piles, abdominal pain fungal infections, reduce tuberculosis, enlargement of spleen, asthma, rheumatism, ulcers, and diabetes (Paul and Bari, 2008; Singh et al., 2012). According to Chakraborty et al. (2015) and Phornvillay et al. (2015), taro has been utilized for the treatment of various ailments, especially neurological disorders, anti-oxidants, and anti-cancer activity. The Santal Tribe people have been used some species of *Colocasia esculenta* and *Alocasia indica* for the treatment of constipation, colic, cough, kidney disease, stomachic, and piles as reported by Mahbubur (2015). According to (Chakraborty et al., and Phornvillay et al., 2015), taro has been utilized for the treatment of various ailments viz. arthritis, asthma, diarrhea, internal hemorrhage, neurological disorders, anti-microbial, anti-ooxidants and anti-cancer activity. Taro starch is easily digestible; hence it is widely used in baby foods, diets of children sensitive to milk and people allergic to cereals as reported by Melese and Negussie, (2015).

Collection and conservation of aroids in BAU-GPC

In Bangladesh there is a wide range of germplasm of aroid, some are edible, and some are very much wild as distinct by their acridity. On the basis of cultivation practices, edible aroids were selected from different localities in the country. In BAU-GPC morphological characterization was done for forty-five germplasms in four genera (*Alocasia, Amorphophallus, Colocasia,* and *Xanthosoma)*. In *Colocasia* five Mukhi Kachu, five Panchamukhi Kachu, five Pani Kachu (*Stoloniferous*) and five Poidnyl Kachu, five in Ol Kachu (*Amorphophallus*), five in Man Kachu (*Alocasia*), eleven in Mowlavi Kachu (*Xanthosoma*). Different germplasms of aroid are cultivated in Bangladesh with various local names without any uniform identity. The germplasms of Man or Mugur Kachu, Pani Kachu, Salad Kachu and Mowlavi Kachu, were propagated by suckers. For the other germplasms, small-sized corms and cormels were used. In the case of Poidnyl or Garo Kachu which produces elongated corms, the apical portions of the corms measuring about 6 cm in length were used.

A list of germplasm collected from different places of Bangladesh and conserved in Bangladesh Agricultural University Germplasm Centre is depicted in Table 1.

Table 1. List of germplasm collected from different place

Genus	Germplasm no. and Local Name	Scientific name	Place of collection
Colocasia	CE-1 (Poitta)	*Colocasia antiquirum*	Chittagong
	CE-2 (Boya)		Bandarban
	CE-3 (Veradosa)		Sathkhira
	CE-4 (Chara)		Bhola
	CE-5 (Meherchandi)		Meherpur
	CE-6 (Iswardi muk)		Iswardi
	CE-7 (Ban mukhi)		Gazipur
	CE-8 (Got/Thama)		Gazipur
	CE-9 (Salad Kachu)	*Colocasia gigantea*	Bandarban
	CE-10 (Panchamukhi Black)	*Colocasia esculenta*	Madhupur
	CE-11 (Panchamukhi Black)		Gazipur

Genus	Germplasm no. and Local Name	Scientific name	Place of collection
	CE-12 (Panchamukhi Green)		Bandarban
	CE-13 (Panchamukhi Black)		Dumuria
	CE-14 (Panchamukhi Green)		Tangail
	CE-15 (Pani-green/Naricali/Kat)		Trishal
	CE-16 (Pani-brown strip/Shola)		Rangpur
	CE-17 (Pani-purple)		Kishorgonj
	CE-18 (Pani-Brown strip)		Jhinaidah
	CE-19 (Pani-brown strip/shola/kali)		Trishal
	CE-20 (Poidnyl- green)/ Bansh/ Garo		Gazipur
	CE-21 (Poidnyl- black)		Gazipur
	CE-22 (Poidnyl- black)		Madhupur
	CE-23 (Poidnyl- black)		Tangail
	CE-24 (Poidnyl- green)		Tangail
Amorphopholus	AC-1 (Madrasi) Ol Kachu	*Amorphopholus campanulatus Roxb.*	Madhupur
	AC-2 (Deshi) Ol Kachu		Bandarban
	AC-3 (Talas) Ol Kachu	*Amorphopholus pirinii*	Panchbibi
	AC-4 (Deshi) Ol Kachu	*Amorphopholus campanulatus* Roxb.	Gazipur
	AC-5 (Madrasi) Ol Kachu		Khulna
Alocasia	AI-1 (Mugur/Man)	*Alocasia indica*	Khulna
	AI-2 (Mugur)		Sathkhira
	AI-3 (Mugur)		Jessore
	AI-4 (Mugur)		Bhola
	AI-5 (Man/Fan)	*Alocasia macrorrhiza*	Trishal
Xanthosoma	XA-1 (Mowlavi)	*Xanthosoma robustum*	Ishwardi
	XA-2 (Mowlavi)		Mowlavibazar
	XA-3 (Mowlavi)		Mymensigh

Genus	Germplasm no. and Local Name	Scientific name	Place of collection
	XA-4 (Bombay/Mowlavi)	*Xanthosoma caracu*	Ishwardi
	XA-5 (Bombay/Mowlavi)		Gazipur
	XA-6 (Bombay/Mowlavi)		Bandarbon
	XA-7 (Shaheby/Babu/Tele /Mowlavi)	*Xanthosoma atrovirens* Koch.	Bhola
	XA-8 (Dud Man/Fan/Mowlavi)	*Xanthosoma sagittifolium* (L) Schott.	Mymensingh
	XA-9 (Surma/Dastar/Krishna/ Kalo/Mowlavi)	*Xanthosoma violacium* Schott.	Gazipur
	XA-10 (Surma/Kalo/Mowlavi)		Lalmonirhat
	XA-11 (Surma/Mowlavi)		Pabna

Mukhi kachu, panchamukhi kachu, pani kachu, poidnyl Kachu, ol kachu, man or mugur kachu are very popular aroids in Bangladesh. Panchamukhi kachu, poidnyl kachu and ol kachu are underutilized tuber crops in northern and southern districts including Chittagong Hill Tracks in Bangladesh. Mukhi Kachu is widely cultivated in many parts of Bangladesh mainly concentrated in Jessore, Meherpur, Kushtia, Chuadanga and Shathkhira (Kundu et al., 2008). The soil and climatic condition of Bangladesh are favorable for Pani Kachu cultivation (Haque et al., 2013). Cocoyams (*Xanthosoma sp.*) are perennial herbs, some with edible corms, others with edible leaves and foliage. Dud Kachu and Mowlavi Kachu (*Xannthosoma sp.*) are mainly cultivated in some areas for their stem and foliage. *Amorphophallus paeniifolius* and *A. campanulatus*, locally known as ol Kachu is a perennial herb with rounded tuberous rootstock (corm) that is widely distributed in Bangladesh. *Alocasia indica* locally known as 'Mugur Kachu' is commercially cultivated in the southern part and homesteads in other parts of Bangladesh. *Alocasia macrorrhiza* is commonly known as Giant taro (Man Kachu or Fan Kachu) is grown in the homesteads of southern and northern parts of Bangladesh. Giant taro grown in a humid environment can tolerate shallow flooding and is frequently found naturally along river banks. List of aroids that are cultivated either in commercial or homestead depicted in Table 2.

Table 2. Growing condition and Commercial cultivation or homestead of Aroids in Bangladesh

Genus	Germplasm no. and Local Name	Growing condition	Commercial cultivation or homestead
Colocasia (*CE1-CE9: Mukhi Kachu*) (*CE10-CE4: Panchamukhi kachu*) (*CE15 to CE19: pani kachu*) (*CE20-CE24:* Poidnyl Kachu)	CE-1 (Poitta)	upland taro	Commercially cultivate
	CE-2 (Boya)	upland taro	
	CE-3 (Veradosa)	upland taro	
	CE-4 (Chara)	upland and saline soil	
	CE-5 (Meherchandi)	upland taro	
	CE-6 (Iswardi muk)	upland taro	
	CE-7 (Ban mukhi)	slightly were wetland taro	
	CE-8 (Got/Thama)	upland taro	
	CE-9 (Salad Kachu)	upland taro	Homestead
	CE-10 (Panchamukhi Black)	upland taro	Commercially cultivate + Homestead
	CE-11 (Panchamukhi Black)	upland taro	
	CE-12 (Panchamukhi Green)	upland taro	
	CE-13 (Panchamukhi Black)	upland taro	
	CE-14 (Panchamukhi Green)	upland taro	
	CE-15 (Pani-green/Naricali/Kat)	wetland taro	Commercially cultivate
	CE-16 (Pani-brown strip/Shola)	wetland taro	
	CE-17 (Pani-purple)	wetland taro	
	CE-18 (Pani-Brown strip)	wetland taro	
	CE-19 (Pani-brown strip/shola/kali)	wetland taro	
	CE-20 (Poidnyl- green)/Bansh/ Garo	high land	Commercially cultivate + Homestead
	CE-21 (Poidnyl- black)	high land	
	CE-22 (Poidnyl- black)	high land	
	CE-23 (Poidnyl- black)	high land	
	CE-24 (Poidnyl- green)	high land	
Amorphophalus (*Ol* Kachu)	AC-1 (Madrasi) Ol Kachu	high land	Commercially cultivate + Homestead
	AC-2 (Deshi) Ol Kachu	high land	
	AC-3 (Talas) Ol Kachu	high land	Homestead
	AC-4 (Deshi) Ol Kachu	high land	Commercially cultivate +
	AC-5 (Madrasi) Ol Kachu	high land	

Genus	Germplasm no. and Local Name	Growing condition	Commercial cultivation or homestead
			Homestead
Alocasia (Man Kachu)	AI-1 (Mugur/Man)	upland	Homestead + Commercially cultivate
	AI-2 (Mugur)	upland	
	AI-3 (Mugur)	upland	
	AI-4 (Mugur)	upland	
	AI-5 (Man/Fan)	upland	Homestead
*Xanthosoma (Bombay/Shaheby/Babu/Surma/*Mowlavi Kachu)	XA-1 (Mowlavi)	upland and drought tolerant	Homestead
	XA-2 (Mowlavi)	upland and drought tolerant	
	XA-3 (Mowlavi)	upland and drought tolerant	
	XA-4 (Bombay/Mowlavi)	upland and drought tolerant	
	XA-5 (Bombay/Mowlavi)	upland and drought tolerant	
	XA-6 (Bombay/Mowlavi)	upland and drought tolerant	
	XA-7 (Shaheby/Babu/Tele/Mowlavi	upland and drought tolerant	Homestead + Commercially
	XA-8 (Dud/ Man/Fan/Mowlavi)	upland and drought tolerant	Homestead
	XA-9 (Surma/Dastar/Krishna/Kalo/Mowlavi)	upland	Homestead
	XA-10 (Surma/Kalo/Mowlavi)	upland	Homestead
	XA-11 (Surma/Mowlavi)	upland	Homestead

Varieties released from GPC collected germplasm

After evaluation of collected germplasm four (04) varieties of aroids were released such as BAU Kachu-1, BAU Kachu-2, BAU Ol Kachu-1 and BAU Man Kachu-1. Description of these released varieties are given bellow

1. **BAU Kachu-1** *(Colocasia esculenta* var. *esculenta)*
   BAU Kachu-1 or Panchamukhi is cultivated commercially in rain-fed upland areas, in the home garden and also paddy field and as intercrops with other crops like pineapples in hilly areas. It is primarily used as vegetable in the scarce period of Kharif season when other vegetables are limited in the markets. It is released for the northern and southern districts including Chittagong and Chittagong Hill Tracts.

Optimum conditions for better yield are 25-30^{0}C, rainfall or irrigation, sandy loam, loose and well-drained soil with pH ranging 6.5 to 6.7. This crop cannot tolerate waterlogging. The best growing season is February to March for planting and October to November for harvesting. Manures and fertilizer applications are needed for batter yield with the rate of Cow dung 15 tons/ha, Urea 200 kg/ha, Triple Super Phosphate 125 kg/ha and Murate of potash 175 kg/ha. Plants are semi-erect in nature. Leaves are heart-shaped and sometimes peltate, petioles are yellowish-green in color. Tubers produce five or more eyes. Cutting of corms is used as seed (Fig. 1). Wedding and drainage can be done when necessary. Annual yield; 40-50 t/ha. Space: 60 x 45 cm for commercial cultivation. BAU Kachu-1 is palatable.

Plant Leaf Tuber Transverse section

Figure 1. Pictorial view of BAU Kachu 1 (Panchamukhi kachu)

2. **BAU Kachu-2 (*Colocasia esculenta* var. *esculenta*)**

BAU Kachu-2 (local name Poidnal) is upland taro that is commercially cultivated in rain-fed high land and hilly areas. This variety is suitable to grow in Madhupur, Gazipur and Chittagong and Chittagong Hill Tracts. Optimum cultivated conditions are 23-31^{0}C, plenty of rainfall (approximately 2362 mm)/irrigation. Sandy loam and loose soil with a good drainage system is recommended as it cannot tolerate waterlogging. Recommended soil pH is 6.6. The petiole of this crop is tall and tan in color. Leaves are heart-shaped and deep green in color (Fig 2). The plant produces cylindrical/ elongated corm and cormels. Cutting of cormel and apical portion of corm with 2 or more eyes are used as seed and planting in maintaining (60 x 45) cm distance. Best time for cultivation is in February to March and Harvest time is November to December. Recommended manures and fertilizers are Cow dung 15 t/ha, Urea 200 kg/ha, Triple Super Phosphate 125 kg/ha and Murate of potash

175 kg/ha. Drainage can be done if necessary. Annual yield; 35-50 t/ha. BAU Kachu-2 is palatable and good in taste.

Plant Leaf Corm Transvers Section

Figure 2. Pictorial view of BAU Kachu 2 (Poidnal kachu)

BAU Ol Kachu-1 (*Amorphophallus campanulatus*)

BAU Ol Kachu-1 can be commercially cultivated in rain-fed upland, in the home garden and with other crops as intercrops. It is locally known as Ol Kachu. It can be found in Pabna, Sathkhira, Khulna, Madhupur Sylhet, Chittagong and Chittagong Hill Tracts.

Ol kachu cultivated in topical areas with 25-35^{0}C. Sufficient rainfall is needed if not then irrigation is applicable. This crop cannot tolerate waterlogging condition. Silty loam and well-drained soil is best for cultivation. Soil pH ranged 5.5 to 6.8 (BARC 1989). Plant has pseudo-stem and medium in height. Leaves are bipinnated. The petioles are light green in colour with white spot on it. Underground tubers are round and conical shaped often produce 2 or more attached cormels. Cutting of corm and cormels are used as seed (Fig. 3). Best time for cultivation on March to April. Harvest time during November to December when the plants are turn into yellow or die back. Manures and fertilizer: Cowdung 15 tons/ha, Urea 200 kg/ha, Triple Super Phosphate 125 kg/ha and Murate of potash 175 kg/ha. Drainage can be done if necessary. Spacing: 75 x 60 cm for commercial cultivation. Annual yield; 40-60 t/ha. BAU Ol Kachu-1 is acceptable, soft and good in taste.

Plant Leaf Corm Transvers Section

Figure 3. Pictorial view of BAU Ol Kachu 1

3. **BAU Man Kachu-1** (*Alocasia indica*)

   BAU Man Kachu-1 can be commercially cultivated in rain-fed areas, in the home garden and also in paddy field islands and intercrops with other crops like banana, coconut tree, and hilly areas with pineapples. It is locally known as Man kachu and Mugur kachu. This variety is mainly recommended in southern districts such as Jessore, Khulna, Bagerhut, Sathkhira, Barishal, and Patuakhali but it can be grown all over Bangladesh.

   It is grown well at 25-30^{0}C temperature with sufficient rainfall. This crop cannot tolerate waterlogging and cold. Sandy loam and slightly saline, loose, deep, around 10-15cm and well-drained soil are best for cultivation. pH ranged from 5.5 to 6.5. Plants are erect and semi-erect in nature. Leaves are peltate, ovate and sagittate shaped (Fig. 4). The petioles are light green in color with brown dot or spots. Underground tubers often produce more suckers. Cutting of corm and apical portion of plant are used as seed. It is a year-round variety but can tolerate cold. Harvest time when old leaves are turned yellow. Recommended spacing is 75 x 60 cm and manures and fertilizer are Cow dung 15 ton/ha, Urea 200 kg/ha, Triple Super Phosphate 125 kg/ha and Murate of potash 175 kg/ha. Drainage can be done if necessary. Annual yield; 40-50 t/ha. BAU Man kachu- 1 is acceptable and good in taste.

Plant   Leaf   Corm   Transverse Section

Figure 4. Pictorial view of BAU Man Kachu 1

Commonly cultivated aroids in Bangladesh

Except for the released varieties, there are different types of aroids/taro is available in Bangladesh. BAU-GPC also collected and characterized those for future research. A few of them are described below.

1. **Mukhi Kachu** (*Colocasia esculenta* var. *esculenta)*
   Mukhi kachu is widely grown in the Garo tribal areas of Modhupur, Haluaghat area of Bangladesh. It is a perennial evergreen herb to 1.5 m tall, with thick shoots from a large corm; slender stolons are also often produced, along with offshoot corms (Fig. 5). Leaf-blades are

60 cm long and 50 cm wide, arrowhead-shaped, with upper surface dark green and velvety; petioles large, succulent, often purplish near the top. Flowers are tiny, densely crowded on the upper part of the fleshy stalk, with female flowers below and male flowers above. Fruit a small berry, in clusters on the fleshy stalk. It can be grown in almost any temperature zone as long as the summer is warm. Growth is best at temperatures between 20 to 30°C. The plants can be damaged if temperatures fall below 10°C for more than a few days.

The stem and leaves are used in the preparation of curry. It is boiled, peeled and fried and used as a side dish with rice. The corm and leaves of Thama kachu are edible. Corms of the small round variety are peeled and boiled. Its leaves are rich in vitamins and minerals.

Plant   Plant harvest   Root   Transverse Section

Figure 5. Pictorial view of Mukhi Kachu

2. **Pani Kachu/Water taro (*Colocasia esculenta* var. *esculenta*)**

Locally known as Pani kachu in Bangladesh is under the genus *Colocasia* of the family Araceae is a perennial aquatic herb with stolon and rhizome, attaining a height of 1.5 m (Fig. 6). It is found in water or standing water almost everywhere in Bangladesh. It is one of the oldest cultivated crops in Asia as well as Southeast Asia and become naturalized in the tropical world. Leaves are showy, large, green, glabrous, triangular-ovate, 30-40 cm long and 20-26 cm wide. Petiole is thick and juicy and it can be almost equal to the height of the plant. New leaves grow from the rhizome. Numerous small flowers are clustered on spadix inflorescence, covered with giant bract leaf, spathe; the spadix is three-fifths of the spathe. Flowering occurs in the rainy season. Fruits are berry, multi-seeded; when ripe, they turn orange. It is propagated by suckers or baby plants originated by rhizomes. Kachur mukhi (Bangla) or corms of the plant, which is a modified stem, is eaten as a delicious vegetable in the country. The size and shapes of corms are different. These are usually round or elongated, painted with light and deep brown color.

These are consumed as vegetables. The whole part of the plant like leaf, stem, petiole, rhizome, stolon everything can be eaten as vegetable. The herb is rich in starch, carbs, sugar and vitamins B and C. Its juice is laxative and used in hemorrhoids. It is used in Hornet bites and Scorpion bites. It is also used in arthritis, asthma, diarrhea, skin disorder, and many other diseases. The plant usually itchy throat when eaten. However, it does not happen by cooking in a special way. It can be planted to enhance the beauty of the water garden.

Plant Leaf Pink Petiole Green Petiole

Figure 6. Pictorial view of Pani Kachu

3. **Jangli Kachu/Wild taro** *(Colocasia esculenta* (L.) Schott var. *antiquorum* (Schott) Hubbard & Rehder)

Wild taro is known as Jangli kachu in Bangladesh belongs to the genus *Colocasia* of the family Araceae. In Bangladesh, it is grown all over the country especially in the plain low land, marshy areas, roadsides. In Bangladesh, it is widely distributed at the district of Mymensingh, Jamalpur, Gaibandha, Rangpur, Kurigram, Comilla, Lalmonirhat, Chittagong, Khagrachori, Rangmati and Dinajpur. It is a perennial evergreen herb (Fig. 7) up to 1.5 m tall, with thick shoots from a large corm; slender stolon often produced, along with offshoot corms. Leaf-blades are 60 cm long and 50 cm wide, arrowhead-shaped, with upper surface dark green and velvety; leaves peltate; petioles large, succulent, and often purplish near the top. The inflorescence is on a fleshy stalk shorter than leaf petioles; part of the fleshy stalk enveloped by a long yellow bract (spathe). Flowers are tiny, densely crowded on the upper part of the fleshy stalk, with female flowers below and male flowers above. Fruit is a small berry, in clusters on the fleshy stalk. Jangli kachu can be grown in almost any temperature zone as long as the summer is warm. Growth is best at temperatures between 20 to 30°C. The plants can be damaged if temperatures fall below 10°C for more than a few days. It is propagated by offshoot corms. The plants are grown year-round in subtropical and tropical areas. The offshoot corms are typically planted close to the soil surface in the months of March and April. The first signs of growth will appear in 1 to 3 weeks. The adult plant needs a minimum at least 1 m^2 of space for good growth. The plants should not be left to go dry for too long; watering will allow the plant to recover if done before they get too dry. Periodic fertilization (every 3 to 4 weeks) with a common plant fertilizer increases yields. Pest and diseases are not usually found to attack the plant.

The corm, stolon and leave petiole of Jangli kachu is edible. It is boiled, peeled, fried and used as a side-dish with rice. Corms of the small round variety are peeled and boiled. Its leaves are rich in vitamins.

Plant Inflorescence Edible Part Wild taro

Figure 7. Pictorial view of Wild taro

4. **Bengal Arum (***Typhonium trilobatum* (L.) Schott)

Bengal Arum, locally known as Ghatkachu, Bishkachu, Ghatu in Bangladesh is under the genus *Typhonium* of the family Araceae. It is also known as kharkon, ghet kachu, chema kachu etc. Ghatkanchu is native to China, Indian Subcontinent, Indochina, Malaysia. Endemic is to tropical Asia, the South Pacific, and Australia. About 50 species: from India to Polynesia; distributions in Africa and the West Indies are the result of human introductions; nine species in China. This strange plant (Fig. 8) has very narrow 3 ft heads emerging before leaves in spring, then unfurl into the only kind of narrow, with intricate maroon and cream patterning. When the leaves do appear, they are large and compound, on a stalk that is light green and black-patterned. It emits a distinctive odor for a few hours when it first blooms. Ghatkanchu grows wild in wet soils. This plant often thrives in poor soil, or disturbed areas with rich soil, because this reduces competition from taller, more aggressive plants. It is fairly drought-tolerant, flowering period is May-July.

The cooked tubers and tender leaves are eaten as vegetables (Fig. 2). Tubers are eaten by the rural people and the plant also has various medicinal uses. The rhizomes, dug up in summer, are well washed, and then dried in the sun or in ovens. Before use, they are soaked in a solution of alum and maceration of ginger, then sliced, impregnated with a decoction of licorice and lightly roasted on a low fire. The rhizome is used for treating vomiting, cough, asthma, sore throat, headache, gastric ulcer, abscess and snake bite.

Plant Edible part

Figure 8. Pictorial view of Bengal Arum

5. **Kata kachu *(Lasia heterophylla* Schott.)**

Kata kachu, is a lean period seasonal vegetable. It is native to India, China, the Indian subcontinent, Indo-China. It is naturally grown in the marshy land of tropical areas. It is also found in India and Bangladesh. Kata kachu (Fig. 9) is characteristically growing 10-90 cm in height with slightly pink petiole, triangular wide shaped leaves and a horizontally growing stolon. It is a plant species of many-nerved, broad-leaved, rhizomatous or tuberous perennials. Kata kachu grows wild in wet soils. This plant often thrives in sterile soil, or disturbed areas with rich soil, because this reduces competition from taller, more aggressive plants. It is fairly drought tolerant plant. Kata kachu is important as food and ethnomedicine Bangladesh. Their bio efficacy is documented in the Ayurveda. The plant’s leaves are collected and cooked in Bangladesh. It is a much favored seasonal vegetable. The plant including the rhizome contains needle-shaped crystals of calcium oxalate known as raphides that are believed to be a defense mechanism against plant predators that can tear and damage the mucus membranes of the throat or esophagus.

Plant Edible part

Figure 9. Pictorial view of Kata kachu plant

6. Buno/Jangli ol *(Amorphophallus bulbifer* Blume ex Decne)

Elephant foot yam or Buno-ol is one of the nutritious corms crops used by poor villagers as vegetables in Bangladesh. It belongs to the genus *Amorphophallus* of the family Araceae. Buno-ol is indigenous to tropical Asia and Africa. It is widely distributed at the district of Mymensingh, Bandarban, Rangmati and Dinajpur. *Amorphophallus* corms varies greatly from species to species. This buno ol produce very small corm. From the top of this corm a single leaf, which can be several metres across in larger species is produced at the top a trunk like petiole and a horizontal blade, which may consist of a number of small leaflets. The leaf lasts one growing season. The plant (Fig. 10) is monocious. One leaf small bulbils are produced which is also edible. Flowers of Buno ol is very attractive. Buno-ol is grown in tropical and sub-tropical climate with low to medium rainfall. The corms rot easily, so the land should be high and well drained, especially during growing season. During dormancy, keeping the soil slightly moist to avoid both rotting and drying out. Temperatures above 80^0F make the leaf die back fast. The safest is to have them stored dry. *Bulbifer* dries out easily, especially when the bulbs are still quite small and that it is best keeping them in moist soil during dormancy. Buno-ol is usually propagated through offsets. Another way to reproduce these plants is leaf bulbils. After the growing season, the leaves are dying back and the bulbs can be harvested. It makes a new plant for next spring. It is not cultivated as a crop in Bangladesh but found in jungles. Pest and diseases are not usually found to attack the plant.

Buno-ol corms are used as vegetables during lean period of vegetables. The petioles of young, unexpanded leaves are edible, when thoroughly cooked. The corm is stomachic and tonic; used in piles and given as a restorative in dyspepsia, debility, etc. It is a hot carminative in the form of a pickle.



Plant Koch and Bouche Edible part

Figure 10. Pictorial view of Buno ol

7. **Bombay / Shaheby / Babu / Surma / Mowlavi Kachu** (*Xanthosoma atrovirens*)

Tannia, locally known as Moulovi kochu in Bangladesh is under the genus *Xanthosoma* of the family Araceae. It is a neglected underutilized plant species mainly grow in shady areas of homestead. Moulovi kochu is native to tropical America and was cultivated in tropical Central and South America from very ancient times. It has been spread widely throughout the tropical world. It is now cultivated in tropical America, the Caribbean, West Africa and the Pacific and to a very limited extent in some other parts of the humid tropics. In Bangladesh, it is mainly distributed in the northern region. Tannia plants can reach a height of about 2 m and have a short erect stem and large, long-stalked sagittate or hastate leaves (Fig. 11), which differ from those of *Colocasia* in that the leaf stalk joins the blade at the margin between the lobes, and the tips of the lobes are pointed. The leaves have a prominent marginal vein and are 50-75 cm long; the petioles are about 1m long. The inflorescence is borne below the leaves, with a pale green spathe. A corm is produced at the base of the plant and this bears several lateral corms (cormels), each 10-25 cm long. Tannia can be successfully grown from sea level up to elevations of about 1500 m. It performs best in tropical conditions but can be grown over a fairly wide range. The crop is suited to high rainfall areas but can be grown with annual rainfall as low as 100 cm provided that this is evenly distributed, although an average rainfall of 140-200 cm is preferable. Tannias can be grown as an upland crop under irrigation and certain early-maturing cultivars can be grown without irrigation in comparatively dry situations. It can be grown on a wide variety of soils, except hard clays or pure sands, but for optimum yields, they require a deep, well-drained, rich soil, preferably with a pH of 5.0-6.5. The crop cannot withstand water logging. Propagation of tannia is mainly practiced by sucker and corm. The best material is small corms or cormels. Alternatively, a 5 cm section can be cut from the main corm, and divided into two pieces across its diameter. Tannias may be grown in monoculture, but are usually grown in crop rotation systems; often they are the first crop in shifting agricultural systems in the hilly areas of Bangladesh. Planting may be throughout the year. The corms or cormels are planted 8-10 cm deep, with the growth bud pointing downwards; if pieces of the main rootstock are used about 2-3 cm is left above the ground. Setts are planted with the base about 10 cm deep. Little attention is given after planting apart from weeding, and sometimes earthing up if planting was on level ground. The wider spacing gives a higher yield per plant, but the wider spacing involves increased maintenance. These spacing distances refer only to tannia grown in monoculture.

In Bangladesh, only the leaves are utilized as vegetable. But in other countries, only lateral corms are used however the lateral corms form the crop. The central (main) corms are usually not eaten for acrid. These edible lateral corms are varying in size from 8 to 30 cm in length and 10 to 20 cm in diameter, and about 80% consists of edible, starchy material, the remainder being a scaly peel. The flesh can be white, yellow or pink. Starchy corms occupy an important place in the diet. These are boiled, baked, or parboiled and fried in oil. The dried peeled corms may be ground to produce flour, which is considered to be as palatable as cassava flour, but more nutritious. About 10 kg of tannias will yield 3 kg of flour. The leaves can be boiled and used as a vegetable too in other countries.

Dud kachu Plant | Surma Kachu Plant | Shaheby kachu Plant | Bombey Kachu Plant | Mowlavi Kachu plant

Rhizom of Dud kachu | Corm of Surma kachu | Rhizom of Shaheby kachu | Corm of Bombey kachu | Rhizom of Moulavi kachu

Figure 11. Pictorial view of Bombay/Shaheby/Babu/ Surma/Mowlavi Kachu

Challenges of aroids cultivation ion Bangladesh

Researchers have been reported that with certain crops such as taro and yams, problematic crops are replacing them. Therefore, it is an urgent need to find out suitable conservation methods that are available and to take the strategy that will protect the region's valuable crop resources. The world's rapid population growth is demanding increased production and greater diversification of crops, expected to reach eight billion by the year 2030 and food production will have to be doubled from the current level of about five billion tons per year (Paul and Bari, 2008). Edible aroids can play major role in addressing this issue.

In Bangladesh, a little work on morphological and molecular characterizations of aroid has been done so far. No intensive scientific research on these crops. Bangladesh Agricultural Research Institute (BARI) initiated some research works on the collection of several germplasms and their morphological and molecular evaluation. A total of 108 aroid germplasms (Pani Kachu 69, Mukhi Kachu 27, Man Kachu 3, Ol Kachu 5 and Dud Kachu 4) were reported (BARI). In addition, BARI has been released one variety of Mukhi Kachu (MK-65) under the name 'Bilashi' and another one is Latiraj (PK-351) which produces a large number of high-quality stolons. More scientific research on these crops is essential to identify these aroid germplasms with their properties and improvement.

Different biotic and abiotic factors are responsible for the low yield of horticultural crops like aroid in Bangladesh which may cause a deleterious effect on yield, good quality, storability, germplasm conservation, distribution. Low production of aroid in Bangladesh is due to (i) Lack of good quality germplasms (ii) Lack of disease-free planting materials, (iii) Lack of production technologies (iv) Pest and diseases, (v) Post-harvest management, etc. Despite its (taro) socio-economic, medicinal and historical importance, the origins, domestication and worldwide distributions of this crop have been neglected. This gap in understanding the history of taro can be partly attributed to the non-suitability of available molecular markers and the scale of targeted plant sampling required as stated by Ahmed (2014). The researchers are interested to know the genetic divergence of different varieties, for assessing the genetic diversity of plant populations in the field. This work can be carried out in different ways such as characterization and evaluation of morphological traits. Because of variable environmental factors in different locations, the field evaluation of morphological characteristics alone is not a completely reliable method. Molecular markers have been useful tools for assessing genetic diversity.

However, the geographical spreading and aroid production may contribute to food, nutrition security, income-generating cash crop, and poverty alleviation in Bangladesh. Moreover, morphological and molecular characterization of aroid germplasms in Bangladesh would improve our knowledge of genetics, also facilitate breeding efforts, protect aroid germplasm from bio-piracy as it is an indigenous crop, hence a national product.

The annual production of aroid is increasing from the past to 2011 around 238645 tons (BBS, 2011). Moreover, the population increasing day by day in Bangladesh while cultivated land is decreasing therefore, we need to utilize the land which is not under cultivation such as river banks, roadside, and unused land. The Giant taro is resistant to most pests and diseases. Panchamukhi Kachu and Ol Kachu have no serious pest and disease also. Aroid is cultivated in small area of land in Bangladesh among other vegetables and the total production is still poor. So, we need to increase the total production of aroid now.

Conclusion

To address the food and nutritional security, the *Colacosia esculenta* (aroids) is considered as one of the most important crops owing to its rhizome and corm production having higher nutritional values in the South Asian region. Not only in this region southeast Asia, Africa and North America are also very popular for aroids. In this region, there is a lack of adequate information for breeding and good variety development. Sharing of varietal material can be an important area for more research. Exchange of variety among the SAARC member states, value addition from aroids, and medicinal value is the best option for further steps. Besides, the aroids also occupy a significant niche as an integral part of alternative medicine in several parts of the world. Aroids or taro are rich in critical minerals, prebiotics, phenolics, antioxidants, anti-cancer compounds etc. In spite of several advantages of, limited efforts are being made for its germplasms collection, evaluation, assessment of nutritional values and varietal improvement. Since the inadequacies of data in some respect getting GI information for complete nutritional data and advanced molecular work is recommended. The future research area of aroids could be carried out in the field of varietal development, post-harvest processing for value-added yam-based products, functional foods and alternative medicinal values.

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Concept note of the Regional Consultation Meeting on the Promotion of Underutilized Taro (*Colocasia esculenta)* for Sustainable Biodiversity and Nutritional Security in SAARC Countries

Genesis: Recommendation of 9th TCARD meeting in Bhutan, June 2019

Introduction

Taro (*Colocasia esculenta* Schott) is a nutrition-rich crop grown throughout the tropical and subtropical regions of the world (Ghosh *et al*., 1988). Taro is an herbaceous, perennial, root crop, largely cultivated for its edible underground corms and cormels, though the whole part of this plant (corm, cormels, leaves, stalk, inflorescence, and flowers) can be used as food. Taro corm and cormels contains about 70-80% starch. The minute size of the starch granules accounts for its excellent digestibility with the concomitant efficient release of nutrients during digestion and absorption (Standal, 1983). Due to high carbohydrate content, Taro plays a critical role in the household, community, and national food security in some parts of the world. Besides a considerable amount of starch, Taro corms and cormels are also rich in vitamin C, calcium, phosphorus, and potassium which are important constituents of human diets (Kaushal, 2015). Taro leaves have been reported to be rich in nutrients including minerals and vitamins such as phosphorous, calcium, vitamin C, iron, riboflavin, thiamine, and niacin.

In South Asian countries it is mainly grown as vegetable and animal feed, although the medicinal and industrial value of Taro is also well documented (Harshal *et al,* 2018). Taro is an ecologically unique crop. It is able to be grown in ecological conditions in which other crops may find it difficult or adverse, such as (i) Waterlogged and hydromorphic soils; (ii) Saline Soils: Some Taro cultivars can tolerate salinity (can grow in 25-50% seawater, such saline conditions would prove lethal to most other crops); and (iii) Shady conditions (can grow well as an intercrop between tree crops (e.g., coconuts), because it can profitably exploit the diffuse light). Taro is one of the world's oldest high nutritious crops and has been used as food for over 9,000 years (Jones, 1998). It occupies a significant place in the agriculture of the Asia-Pacific Region.

Currently, global food security is largely dependent on a handful number of crops. Modern agricultural systems promote the cultivation of high-yielding crop species, with the intensification of a limited number of species. This has caused a decline in the cultivation of traditional crops, yet such crops have the potential to improve food and nutritional security for the current increasing population in the world. To address the demand for increased production and greater diversification of crops, Taro can play a major role in this context. Some varieties of edible Taro and aroids are endemic in nature. Being cultivated in particular geographic areas, their merits may not be well evaluated. In spite of tremendous potentialities, edible Taros are not getting proper attention and becoming vulnerable to diseases, pests, etc. In this perspective, this workshop will be undertaken with the following objectives.

Objective

- To create awareness on the nutritive, medicinal, and industrial values and diversified uses of Taro
- To update on current country status with challenges for further development
- To share knowledge on a possible way to develop mechanisms for regional cooperation for developing a program on Taro (such as pest and diseases, germplasm collection and breeding for better keeping quality, etc.)

Methodology

- Three days' workshop
- Country status will be shared by the participant by country paper presentation
- Brainstorming, group work, and round table discussion will be organized
- A field visit for getting practical experiences

Expected Output

- Current status on production, consumption, and research of Taro will be updated
- Constructive suggestions will be harvested for effective regional cooperation for Taro development
- Further programs can be planned from the recommendation from group work, brainstorming and field visits.

Participants: About 10 regional experts, 1 from each country, including tuber crops researchers, extensionists, and other relevant persons who are involved in Taro development projects in the SAARC Member States. In addition, tuber crops experts will be invited for a round table discussion from the host country.

Date: 03-04 November

Meeting Type: Online

Meeting platform: Zoom

Reference

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Report on Regional Consultation Meeting on the Promotion of Underutilized Taro (*Colocasia esculenta*) for Sustainable Biodiversity and Nutritional Security in SAARC Countries

Brief summary

The Regional Consultation meeting on the Promotion of Underutilized Taro (*Colocasia esculenta*) for Sustainable Biodiversity and Nutritional Security in SAARC Countries was held on 03-04 November 2020 in virtual mode. This consultation meeting aimed to exchange the current status of research and development on production and utilization of Taro in the SAARC Member States, along with the challenges facing for its further extension, and to harvest recommendations from regional experts for possible ways to develop mechanisms for regional cooperation for promoting Taro in the SAARC Region.

The inaugural session of the consultation meeting was chaired by Dr. Mian Sayeed Hassan, Director, SAC, Mr. Md. Shamsul Haque, Honorable Additional Foreign Secretary (SAARC and BIMSTEC), Ministry of Foreign Affairs, Bangladesh graced the session as the Chief Guest and Dr. Sheikh Mohammad Bokhtiar, Executive Chairman, Bangladesh Agricultural Research Council attended as the Special Guest. The Program was coordinated by Dr. Nasreen Sultana, Senior Program Specialist (Horticulture), SAC. A total of 20 participants, two from each of the SAARC Member State (except Afghanistan) and six invitees attended the zoom meeting. In addition, all SAC professionals also attended the meeting.

At the onset of the meeting, welcoming all participants, the Director of SAC highlighted the importance of organizing this consultation meeting. He extended his gratitude to all the Member States for nominating participants for this virtual meeting. Recalling his emotional attachment with SAC as director for the last five years, Dr. Bokhtiar accentuated the significant achievements of the SAC during his tenure such as establishing the SAARC Ph.D. scholarship program, multi-country projects, etc. Stressing the importance of Crop Biodiversity in the SAARC region he stated that Material Transfer Agreement should be reinforced for the betterment of regional agriculture. Thanking SAC for inviting him as the Chief Guest of the session, Mr. Md. Shamsul Haque expressed that it was a great opportunity for him to interact with regional experts. He mentioned that COVID-19 has led a situation to look back, think, rethink and also learn, relearn and unlearned the ways of our works. Emphasizing the nutritional, medicinal and industrial value of taro he stated that SAC is the right platform to promote this type of potentially underutilized crops and called on all SAARC Member States to work together. Wishing the success of the two days consultation meeting he said that the recommendations of the meeting should be reached to the policymakers.

After the inauguration, the program was divided into three technical sessions. In the first session, three-country status papers were presented under the session chairmanship of Dr. M A Jalil Bhuiyan, a renowned Horticulturist in Bangladesh. In this session Dr. Md. Shamshul Alam, Senior Scientific Officer, Tuber Crops Research Centre, Bangladesh Agriculture Research Institute, Mr. Ngawang, Program Director, Agriculture Research and Development Centre, Bhutan and Dr. V. Ravi, Director, ICAR-Central Tuber Crops Research Institute orated the overview of country status paper of Bangladesh, Bhutan and India, respectively.

The second technical session was chaired by the famous Professor of Horticulturist in Bangladesh Agriculture University (BAU), Mymensingh Dr. M.A. Rahim. During this session, four-country status papers were presented by the representatives of Maldives, Nepal, Pakistan, and Sri Lanka. Mr. Gasith Mohammd, Director, Ministry of Fisheries, Marine Resources and Agriculture, Maldives, Mr. Yubaraj Bhusal, Chief of Horticultural Research Station, Nepal, Dr. Amir Sultan, Principal Scientific Officer National Herbarium of Bio-resources Conservation Institute, National Agricultural Research Center, Islamabad, Pakistan, and Dr. R.L. Senanayaka, Assistant Director (Research), Department of Agriculture, Pakistan, presented the papers, respectively.

The third session was chaired by Dr. Mian Sayeed Hassan, Director, SAC. Three invited speakers spoke in this session. Dr. M.A. Rahim, Professor, Dept. of Horticulture, BAU, spoke on the research and development of Taro in Bangladesh. The second paper was presented by Mr. Md. Helal Uddin, South Asia Advocacy Coordinator, Action-Aid International, Bangladesh, on Promotion of Underutilized Taro focusing biodiversity and gender issue in South Asian context, and the third paper focusing the Potentials of Taro in Food and Nutrition Security in SAARC Countries was presented by Dr. Md. Saleh Ahmed, President, Bangladesh Society of Horticultural Science. After a discussion of recommendations, the program was concluded by the Director of SAC with the closing remarks.

Objectives

The main objectives of the consultation meeting were:

- To create awareness on the nutritive, medicinal, and industrial values and diversified uses of Taro

- To update on current country status with challenges for further development
- To share knowledge on the possible way to develop mechanisms for regional cooperation for developing a program on Taro (such as pest and diseases, germplasm collection and breeding for better keeping quality, etc.)

Salient achievements

- Fourteen (14) experts of seven SAARC member States (Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, and Sri Lanka) joined the program.
- Ten (10) articles were presented and discussed in the meeting. Among which seven were by seven regional experts and three (03) were by the experts of the host country.
- A set of questions were prepared and sent to the participants the previous night to brainstorm and include the points which were not reflected in the presentation for facilitating the recommendation session on the second day.

Challenges

- Receiving nominations from member states on time was a big challenge.
- Interruption in Internet connection.

Lessons Learned

- The Member States are very much interested in awareness development on underutilized crop-taro
- Participants showed interest in working together on research and development for diversified and locally grown nutritious crops like taro.
- Virtual meetings can be organized effectively with the SAARC Member States if planned timely and ensured uninterrupted IT supports.
- Host country experts (other than government nominees) are also very much interested in working with SARRC Agriculture Centre and sharing their knowledge with regional experts.

PROGRAM (Mode: Virtual)

REGIONAL CONSULTATION MEETING ON Promotion of Underutilized Taro (*Colocasia esculenta*) for Sustainable Biodiversity and Nutritional Security in SAARC Countries

Date: 03-04 November 2020
Organizer: SAARC Agriculture Centre (SAC)
Dhaka, Bangladesh

Join Zoom Meeting link:
https://us02web.zoom.us/j/85308292958?pwd=cFhnUzNYcFd5T3M0SytSUjhCYUdmdz09

Meeting ID: 853 0829 2958
Passcode: UT2020

DAY 1: 03 November 2020 (Tuesday)

Inaugural Session: Virtual Mode			**Duration**
10:20-10:30	Guests take their seats and Log in with Zoom ID		10 min
10:30-10:35	Welcome Remarks	Dr. Mian Sayeed Hassan, Director, SAARC Agriculture Centre (SAC)	5 min
10:35-10:45	Remarks by Special Guest	Dr. S.M. Bokhtiar , Chairman, Bangladesh Agricultural Research Council (BARC)	10 min
10:45-10:55	Remarks by Chief Guest	Mr. Md. Shamsul Haque, Addl. Foreign Secretary (SAARC & BIMSTEC), Ministry of Foreign Affairs, Bangladesh	10 min
10:55-11:15	Photo session and Tea break		15 min

Inaugural Session: Virtual Mode			**Duration**
Technical Session 1: Country Paper Presentations Chairperson: Dr. Abdul Jalil Bhuyian, Consultant, NATP-2 Program Coordinator: Dr. Nasreen Sultana, Senior Program Specialist (Horticulture); Rapporteur: Fatema Nasrin Jahan, Senior Program Officer (NRM), SAC and Dr. Younus Ali, Senior Technical Officer, SAC			
11:15-11:20	Briefing about the Program	Dr. Nasreen Sultana, Senior Program Specialist (Horticulture)	05 min
11:20-11:40	**Afghanistan**	Due to internet disruption, no presentation was done	20 min
11:40-11:50			10 min
11:50-12:10	**Bangladesh**	Mrs. Tajkera Khatun, Joint Secretary, Ministry of Agriculture and Dr. Md. Shamul Alam. SSO, TCRC, BARI	20 min
12:10-12:20		Discussion	10 min
12:20-12:40	**Bhutan**	Mr. Ngawang, Program Director, ARDC and Mr. Sangay Dorji, Senior Agriculture Supervisor, ARDC	20 min
12: 40-12:50		Discussion	10 min
12:50-13:10	**India**	Dr. Vikramaditya Pandey, Assistant Director General (Horticulture Science), ICAR and Dr. V. Ravi, Director, ICAR-Central Tuber Crops Research Institute (CTCRI)	20 min
13: 10-13:20		Discussion	10 min
13:20-13:25	Closing remarks by Chairperson		05 min
13:25-14:30	Lunch break		60 min
Technical Session 2: Country Paper Presentations			
Chairperson: Dr. M.A. Rahim, Professor, Dept. of Horticulture, BAU Program Coordinator: Dr. Nasreen Sultana, Senior Program Specialist (Horticulture); Rapporteur: Fatema Nasrin Jahan, Senior Program Officer (NRM), SAC and Dr. Younus Ali, Senior Technical Officer, SAC			
14:30-14:50	**Maldives**	Mr. Ismail Rasheed, Director, Ministry of Fisheries, Marine Resources and Agriculture (MoFMRA) Mr. Gasith Mohammd, Director, MoFMRA	20 min
14:50-15:00		Discussion	10 min
15:00-15:20	**Nepal**	Mr. Surya Prasad Baral and Mr. Yubaraj Bhusal	20 min
15:20-15:30		Discussion	10 min
15:30-15:50	**Pakistan**	Dr. Amir Sulta, PL/ Principal Scientific Officer (PSO), (National Herbarium), Bio-resources Conservation Institute (BCI), PARC-NARC and Dr. Asif Javaid, PSO, BCI, PARC-NARC	20 min
15:50-16:00		Discussion	10 min

Inaugural Session: Virtual Mode			Duration
16:00-16:20	**Sri Lanka**	Dr. R. L. Senanayaka, Asst. Director (Research), Department of Agriculture Mrs. N. L.A. T.S. Nanayakkaram, Asst. Director (Research), DoA	20 min
16:20-16:30		Discussion	10 min
16:30-16:35	Closing remarks by Chairperson		05 min

DAY 2: 04 November 2020 (Wednesday)

Inaugural Session: Virtual Mode			Duration
Technical Session 3: presentation by Guest speaker and Recommendation Chairperson: Dr. Mian Sayeed Hassan, Director, SAC Program Coordinator: Dr. Nasreen Sultana, Senior Program Specialist (Horticulture); Rapporteur: Fatema Nasrin Jahan, Senior Program Officer (NRM), SAC and Dr. Younus Ali, Senior Technical Officer, SAC			
10:30-10:50	Promotion of Underutilized Taro (*Colocasia esculenta*) focusing research and development in Bangladesh/ SAARC Countries	Dr. M. A. Rahim, Professor, Dept. of Hort., Bangladesh Agricultural University (BAU)	20 min
10:50-11:10	Promotion of Underutilized Taro (*Colocasia esculenta*) focusing on Biodiversity and gender in South Asian Context	Mr. Md. Helal Uddin, South Asia Advocacy Coordinator, ActionAid, International, Bangladesh	20 min
11:10-11:30	Promotion of Underutilized Taro (*Colocasia esculenta*) focusing potentials of Taro in Food and Nutrition Security in SAARC Countries	Dr. Saleh Ahmed, President, Bangladesh Society of Horticulture Science (BSHS) and Chairman Kernel Foundation, Bangladesh	
11:30 -11:50	Open discussion/ question-answer to guest speakers	All participants	20 min
11:50-12.30	Recommendation session	Participants and Program Coordinator	40 min
12:30-12:45	Presentation by the group	Rapporteurs /Coordinator	15 min
12:45-12:50	Closing remarks by Chairperson		05 min

List of participants

Country	Name	Designation	Contact
Afghanistan			
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Country	Name	Designation	Contact
		Development	
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Pakistan	Dr. Amir Sultan	PL/ Principal Scientific Officer (National Herbarium), Bio-resources Conservation Institute (BCI), NARC	Amirsultan2000@yahoo.com 0301 5339060
	Dr Asif Javaid	Principal Scientific Officer/ Program Leader/ Genebank, Curator, Plant Genetic Resources Program, BCI, NARC	+92 51 90733715 javaidpgri@gmail.com
Sri Lanka	Dr. R. L. Senanayaka	Asst. Director (Research)	revisena@gmail.com +94-77-9027794
	Mrs. N. L.A. T.S. Nanayakkaram	Asst. Director of Agriculture (Research)	subodhinit@gmail.com +94-71-3520610
Invited speakers	Dr. M.A. Rahim	Professor, Dept. of Horticulture, BAU	marahim1956@bau.edu.bd +880 1711854471
	Dr. Saleh Ahmed	President, Bangladesh Society for Horticultural Science	saleh4s@yahoo.com +880 1712740107
	Mr. Helal Uddin	South Asia Advocacy Coordinator, Action Aid, International, Bangladesh	Helal.Uddin@actionaid.org +880 1552476904
Invited participants	Md. Amirul Islam	Operations Manager for S/C Asia Asian Farmers Association for Sustainable Rural Development (AFA, Bangladesh	afaamir@asianfarmers.org +880 1716152724
	Mr. Mustafa Mirani,	Vice-Chair, SSAFP, and Secretary of Pakistan Fisher Folk Federation (PFF) Pakistan	mustafa.mirani@gmail.com
	Ms. Sarita	Chairperson, Solidarity	bhusalsarita@gmail.com

Country	Name	Designation	Contact
	Bhusal,	of South Asian Farmers and Producers and Member of All Nepal Peasant Federation (ANPF) Nepal	
Participants of SAC	Dr. Ashis Kumar Samanta	Senior Programme Specialist (Livestock)	draksamanta@sac.org.bd , drashiskumarsamanta@gmail.com +8801316195379
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BACKGROUND WORK ON RECOMMENDATION SESSION

of

Regional Consultation meeting on the Promotion of Underutilized Taro for Sustainable Biodiversity and Nutritional Security in SAARC Countries

Dear esteemed expert members of SAARC Member States, you are requested to respond to the following questions to accelerate the facilitation procession of recommendations session tomorrow. Please send it by as soon as you complete it. Thanks for your time and active participation. I am very much grateful to you for your dedication.

Note: you may add or delete rows in the tables based on your need.

1. Do you think Taro is an underutilized crop in your country? Please Justify your answer "yes", or "No" in the table below:

Yes

Name your country	Your comment	Please Substantiate/Justify the reason

2. Do you think people of your country are aware of the nutritive value of taro? Please comments in the table below supporting your answer.

Name your country	Your comment reasons	Justification

3. Do you think market players (processing industry, bakery, pharmaceuticals) and policymakers (export policy, etc.) are aware of the industrial use of taro? Please comment on the table below.

Name your country	Your Comment	Possible justification

4. What are the major challenges of promoting taro in your country?

Name your country	Challenges	suggestions to overcome it

5. Please suggest some Need-Based Programs (e.g., Training, exposure visit, consultation meeting, etc.) to SAC for immediate action (Next year's program).

Name your country	Program	Your suggestions

6. Suggests possible ways to develop mechanisms for regional cooperation for promo?

Name your country	what	How

7. Please comment on the role of Taro in maintaining biodiversity and cropping diversity.

Name your country	Your comment	Justification

8. How your country can cooperate with other member states for promoting Taro?

Name your country	Your interest/commitment	How to materialize

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